

former(s). This transformer may be mounted on a pad outside the building, on a pole outside the building or in a vault. Documentation of the transformer could include the transformer's nameplate and connections. If the transformer is accessible, the system voltage, output voltage, number of phases, and, in the case of multiple phases, the wiring configuration could also be documented. The investigator may need assistance from the electric utility provider regarding information about the electric service.

✓ **9.12.5.2** Documentation of the electric service could include the visual observation of service conductors, including their size and physical condition. Portions of these conductors may be underground or overhead as they are routed to the building.

✓ **9.12.5.3** If the electric service to the building or facility was disconnected or opened, the investigator should determine how and when this was done. This information will rarely come from the physical evidence and will most usually come from sources such as interviews, radio logs, or other manually recorded information. This data may be important in determining the time-sequence of any arc sites, or lack of arc sites, found within the building or facility. Any arc sites must have been created before the building was de-energized.

✓ **9.12.5.4** The electric service for the building may include additional components such as the weatherhead, service raceway, underground conduit and conductors, service disconnect(s), and the meter socket enclosure. Documentation of the electric service includes the physical condition, rating, electrical connections, and status of relevant switches, circuit breakers, or fuses.

✓ **9.12.5.5** If the electric meter is present, the investigator should photograph and document its condition. If the electric meter is a plug-in type, the investigator should coordinate with the electric utility provider to remove the electric meter. If the electric meter is removed, the investigator can examine the condition of the electrical connections, including insulating boots if present.

✓ **9.12.5.5.1** If the electric meter is a smart meter [i.e., connected to an advanced metering infrastructure (AMI)], the investigator may want to obtain energy usage data from the electric utility provider. This data can aid in determining loads at various times leading up to the incident. It can also aid in determining when the facility was de-energized. To perform this analysis, the investigator should gain an understanding of how the local electric utility provider obtains smart meter data through the local AMI. This specifically includes the definitions of monitoring intervals and upload frequency. The question of who owns this data varies by jurisdiction. The investigator needs to understand who owns the data and the administrative requirements for obtaining such data. The investigator should keep in mind that the usage data leading up to the incident may exist partially at a remote location and partially on the meter. Therefore, any handling of the meter should be coordinated with the electric utility provider to protect the data that is stored on the meter and minimize data loss.

✓ **9.12.6 Premises Wiring System.** The premises wiring system includes, but is not limited to, items such as panelboards, fuses, outlets, receptacles, switches, disconnects, and cables or conductors. The following information should be considered for collection in the examination of the premises wiring system. The necessity for obtaining any particular information will be

dictated by the circumstances of the incident. Where the term *condition* is used, it is generally based upon a visual observation although some circumstances may require more in-depth analysis that may occur at later examinations.

N 9.12.6.1 The portions of the premises wiring system within the structure examined by the investigator may be defined by the portion(s) of the building damaged by the fire or by other factors such as witness statements and video recordings. Often, at fire scenes, only a portion of the building's electrical distribution system will need to be examined.

N 9.12.6.2 Panelboards associated with equipment in the areas of interest should be examined and documented. This examination might include, but is not limited to, the following:

- (1) Documenting the exterior condition of the panelboard
- (2) Noting the positions of circuit breakers (i.e., on, tripped, off) or state of fuses
- (3) Recording and photographing any panelboard schedules and other markings
- (4) Determining if any circuit breakers were disturbed during or after the fire suppression operations
- (5) Removing the cover and documenting the interior.
- (6) Examination of all conductor entry points and terminations
- (7) If possible, nondestructively examining the condition of the circuit breakers and their connections to the panelboard bus bars
- (8) Looking for burned or melted wire insulation
- (9) Documenting panelboard grounding and bonding connections
- (10) Identifying modifications
- (11) Examining the cabinet or enclosure for evidence of arc melting or arc sites

N 9.12.6.3 The wiring associated with the premises wiring system may be inside walls or relatively inaccessible. It may be advantageous to the investigator to examine the electrical equipment not associated with the premises wiring system, such as cord and plug devices, products, or appliances, in the fire damaged areas before examining the conductors associated with the premises wiring system.

N 9.12.7 Other Than Premises Wiring System and Appliances.

N 9.12.7.1 In compartment fires, cord and plug wiring are often subjected to heat before the premises wiring system, which may be protected by barriers such as gypsum board. These cord and plug conductor sets include, but are not limited to, appliance wiring, appliance cord sets, extension cords, and relocatable power taps. These items should be examined to determine if arc sites are present on the conductors.

N 9.12.7.2 Appliances and building equipment may contain arc sites located internally. The investigator should consider spoliation issues when considering the disassembly of any appliance or product at the fire scene to locate arc sites on internal conductors. The investigator may need to collect such electrical equipment, appliances, or products for later examination at another location with the appropriate parties present.

N 9.13 Arc Surveys. As part of the examination of an electrical system, an investigator should conduct an arc survey by examining the structure's electrical system for arc sites to aid in the determination of the fire's origin and to determine its spread. This methodology is based on the behavior of energized electrical circuits exposed to a spreading fire. In some cases, the

spatial relationship of the arc sites to the structure and to each other can be used in an analysis of the sequence in which the parts of the electrical system were impinged by heat or flame. This sequential data can be used in combination with other data to define the area of origin.

N 9.13.1 Procedures and Limitations. The identification of arc sites in the area of fire origin may help to identify a potential ignition source(s) for consideration. The locations of arc sites on conductors that are exposed to the developing fire, such as appliance cords, branch circuit conductors, or feeders that are in the compartment of the fire, may provide the most useful information.

N 9.13.1.1* Arc surveying involves several processes, including arc identification. The arc sites first need to be found and then documented. There are a number of ways to do this work, but all seek to develop relationships among the location of the arc sites themselves as well as the relationship of the arc sites to other evidence, such as ignition sources, in the fire scene. Depending upon the requirements, some fire scenes may only be partially arc surveys or arc surveys may only be applied to a particular piece of equipment.

N 9.13.1.2 If a complete arc survey is not performed in the fire-damaged areas (i.e., portions of the building or portions of conductors are not examined), conclusions drawn from the arc survey are limited to the area that was actually examined.

N 9.13.1.3 The arc survey involves the identification and recognition of the characteristics of arc melting and knowledge of the electrical system. A metallurgist or materials scientist may assist in determining whether a particular conductor anomaly is the result of an arc or other damage.

N 9.13.2 Arc Map. An arc map is a product of the arc survey. The arc survey is conducted during the electrical system examination. The arc map is a representation of the physical location on the circuits where the arc sites formed.

N 9.13.2.1 Several pieces of data should be recorded when creating an arc map. This includes information about conductor damage resulting from the arc. The arc may have caused conductors to sever, weld together, or locally melt. In the event of multiple arc sites on a circuit, if present, the furthest downstream severing arc site should be documented. In addition, for the arc map to be useful in evaluating fire patterns, the arc map should indicate if there are any factors which would protect the circuits from arcing such as thermal barriers. Some examples might include where appliance cords are behind furniture, or where building conductors are behind compartment walls or ceilings.

N 9.13.2.2 The type of circuit protection and its status should be recorded for each circuit examined. This examination should include the presence of circuit protection devices such as over-current protection devices for each circuit, fuses, circuit breakers, ground fault circuit interrupters (GFCI), arc fault circuit interrupters (AFCI), or similar devices.

N 9.13.3 Locating Arc Sites.

N 9.13.3.1 Arc sites may potentially be found on conductors, on conduit, and on grounded surfaces or surfaces of a different voltage potential. In some cases, arcing may involve materials that are not normally considered typical electrical conductors. Large arc sites through conduit can be observed, particularly when they involve higher voltages and fault currents associated

with electrical distribution within a large plant or commercial building. Power from such circuits, still considered low-voltage (<1000 V) according to *NFPA 70*, can provide sufficient energy for substantial arcing damage to both conductors and conduit. Holes created by arcing are typically large enough to be easily seen during a thorough examination of the conduit. The presence of a hole in conduit may be indicative of arcing, but the absence of holes does not indicate the absence of arcing. A conduit survey that only looks for holes is not an arc survey. Alloying or external effects may also create holes in conduit.

N 9.13.3.2 For conductors in conduit, it is necessary to remove the conductors from the conduit to perform a visual examination. In this case, the conductor sections should be maintained in the same orientation as the conduit. They may be laid out next to the conduit so that comparisons can be made between any sites of interest and the conduit. Maintaining the orientation also assists in documenting any findings. Retention of the conductors may be accomplished either by using wire ties and securing them to the conduit from which they were removed or, if their ductility permits, rolling them into a coil. Caution is required when removing conductors from conduit because the conductors may be adhered to the conduit as a result of welding at an arc site, corrosion, and charred or melted insulation. In addition, brittle conductors may break during removal. After removal of conductors from the conduit, they should be thoroughly examined. If the conductors cannot be removed from the conduit, radiographic analysis may be considered to identify any abnormalities inside the conduit. If necessary, the investigator should collect the conduit for later examination at another location with the appropriate parties present.

N 9.13.3.3 Conductors and conduit require a thorough examination to locate the arc sites. An adequate examination requires visual and tactile access to the entire circumference of the conductor. In addition, the examination requires bright, task-oriented lighting. The most frequently used method of examination involves running lightly gloved hands along the length of the examination subject while using bright, oblique lighting to visually observe shadows cast by the light source. This sensory input provides two sensory inputs to assist in locating anomalies. Because arc sites as small as 1 mm (3/64 in.) have been documented, it is important that the examiner has full and ready access to the entire circumference of the subject of the examination.

N 9.13.3.4 After being documented in their as-found condition, removal of loose insulation and similar material may be necessary to view the conductors. Due to copper's relatively low hardness, extreme care should be taken in using any harder tools, such as steel pliers. Nondamaging tools, such as nylon brushes and bamboo skewers, may be used for removal of this material with relatively little risk of copper damage. The use of fiberglass and brass brushes may damage the fine surface features used to identify arc sites.

N 9.13.3.5 It is appropriate to either examine the electrical system during the site examination or remove the components for later laboratory examination. That decision may be influenced by a short duration of site availability, a pressing need to quickly determine the area of origin, or adverse site conditions. If the electrical components are to be removed for later examination, those components should be marked to enable removal and later examination while maintaining appropriate orientation with respect to the scene or the circuit.

N 9.13.4 Documenting the Damage.

N 9.13.4.1 In many instances, the area to be included in the arc survey can be reduced or confined by factors such as a limited area of fire damage, eyewitness accounts, video or photographic documentation of the fire in early stages, or fire alarm data. If an arc survey is being done for the purpose of origin determination, then the physical location of the arc site in the building and its relationship to potential ignition sources and fuels is important and therefore should be noted.

V 9.13.4.2 An effort should be made to identify any corresponding areas of damage related to a potential arc site. That means that the ungrounded conductor side and the grounded side or sides, or two or more conductors of differing potentials (i.e., voltages), are located to demonstrate the complete circuit related to the fault and the corresponding area(s) of damage. Identifying two or more corresponding areas of damage associated with the fault increases the probability that a true arc site has been identified. Corresponding areas of arc damage should be photographed. As with other documentation, this should include both overview and close-up photos.

V 9.13.4.2.1 Although not always possible due to collapse and other damage to circuits, the documentation should identify the circuit upon which the arc site was found. This can be facilitated by marking on building drawings or using surveying tools or similar techniques to locate the arc sites or artifacts.

V 9.13.4.3 To document arc sites, attach visible markers such as colored ribbon, colored cable ties, or tape to the conductors and document using photographs or video. Should the need exist to take evidence of the arc site, then one can collect the electrical circuits of interest. Collecting each circuit, both those that arced and those that did not, will be of value only if the spatial relationship of the circuits is sufficiently documented. The spatial relationship between arc sites and energized conductors without arc sites should be considered and recorded.

N 9.13.4.4 In the event that a portion of the conductor will be removed and retained, it should be documented in the same way as other evidence.

N 9.13.4.5 The absence of arc melting can be important evidence and should be noted so that it is clear that the particular area was examined, but that no arc sites were found. Progress photos, much like photography during delayering, can assist in documenting these findings.

N 9.13.4.6 Areas of melted conductors should also be documented. Areas of melting of the conductors may have reduced the ability to identify arc sites on the conductors. Investigators should consider the possibility that arc sites were obscured or destroyed by the subsequent fire induced melting. These locations of melting should be captured photographically. In some cases, it can be helpful to take sample pieces as documentation of the nonarc observations. Melted copper can assist in understanding temperature distributions within the compartment. Documentation of the melted copper locations can be helpful in understanding the fire scenario.

N 9.13.4.7 The identification of arc melting within a scene, without any other data, is only indicative of the item being energized when the arc melting occurred. If the investigator identifies an artifact as damage caused by arc melting, the investigator needs additional data to determine whether or not

the damage is located in or near the area of origin or is a potential ignition source.

9.14 Static Electricity.

9.14.1 Introduction to Static Electricity.

9.14.1.1 Static electricity is the electrical charging of materials through physical contact and separation and the various effects that result from the positive and negative electrical charges formed by this process. Static electricity is accomplished by the transfer of electrons (negatively charged) between bodies, one giving up electrons and becoming positively charged, and the other gaining electrons and becoming oppositely, but equally, negatively charged.

9.14.1.2 Common sources of static electricity include the following:

- (1) Pulverized materials passing through chutes or pneumatic conveyors
- (2) Steam, air, or gas flowing from any opening in a pipe or hose, when the stream is wet or when the air or gas stream contains particulate matter
- (3) Nonconductive power or conveyor belts in motion
- (4) Moving vehicles
- (5) Nonconductive liquids flowing through pipes or splashing, pouring, or falling
- (6) Movement of clothing layers against each other or contact of footwear with floors and floor coverings while walking
- (7) Thunderstorms that produce violent air currents and temperature differences that move water, dust, and ice crystals, creating lightning
- (8) Motions of all sorts that involve changes in relative position of contacting surfaces, usually of dissimilar liquids or solids

9.14.2 Generation of Static Electricity.

9.14.2.1 **General.** The generation of static electricity cannot be prevented absolutely, but this generation is of little consequence because the development of electrical charges may not in itself be a potential fire or explosion hazard. For there to be an ignition, there must be a discharge or sudden recombination of the separated positive and negative charges in the form of an electric arc in an ignitable atmosphere. When an electrical charge is present on the surface of a nonconducting body, where it is trapped or prevented from escaping, it is called static electricity. An electric charge on a conducting body that is in contact only with nonconductors is also prevented from escaping and is therefore nonmobile or *static*. In either case, the body is said to be *charged*. The charge may be either positive (+) or negative (-).

9.14.2.2* **Ignitable Liquids.** Static is generated when liquids move in contact with other materials. This phenomenon commonly occurs in operations such as flowing through pipes, and in mixing, pouring, pumping, spraying, filtering, or agitating. Under certain conditions, particularly with liquid hydrocarbons, static may accumulate in the liquid. If the accumulation of charge is sufficient, a static arc may occur. If the arc occurs in the presence of a flammable vapor-air mixture, an ignition may result.

9.14.2.2.1 Filtering with some types of clay or microfilters substantially increases the ability to generate static charges. Tests and experience indicate that some filters of this type have

the ability to generate charges 100 to 200 times higher than achieved without such filters.

9.14.2.2.2 The electrical conductivity of a liquid determines its ability to accumulate and hold a charge. Liquids with very low conductivity do not have enough free charges to accumulate a significant charge. Liquids with very high conductivity have enough charges, but the charges cannot accumulate to a significant degree. Consequently, the high-hazard liquids are those with intermediate conductivity (see Table 9.14.2.2.2). The units for conductivity are siemens per meter, abbreviated as S/m. A siemens is the reciprocal of the ohm.

9.14.2.3 Charges on the Surface of a Liquid. If an electrically charged liquid is poured, pumped, or otherwise transferred into a tank or container, the unit charges of similar polarity within the liquid will be repelled from each other toward the outer surfaces of the liquid, including not only the surfaces in contact with the container walls but also the top surface adjacent to the air or vapor space, if any. It is the latter charge, often called the *surface charge*, that is of most concern in many situations. In most cases, the container is of metal, and hence electrically conductive.

9.14.2.3.1 Even if the tank shell is grounded, the time for the charge to dissipate, known as relaxation time, may be as little as a few seconds up to several minutes. This relaxation time is dependent on the conductivity of the liquid and the rate and manner that the liquid is being introduced into the tank, therefore, the rate at which the electrostatic charge is being accumulated.

Table 9.14.2.2.2 Common Liquids That Have Conductivity

Hazard	Example substances	Typical electrical conductivity (S m ⁻¹)
Low: conductivity less than 10 ⁻¹³	hexane	10 ⁻¹⁷
	carbon disulfide	8×10 ⁻¹⁶
	benzene	5×10 ⁻¹⁵
	heptane	3×10 ⁻¹⁴
High: conductivity of 10 ⁻¹³ to 5×10 ⁻¹¹	xylene	10 ⁻¹³
	dioxane	10 ⁻¹³
	toluene	10 ⁻¹²
	cyclohexane	2×10 ⁻¹²
	styrene	10 ⁻¹¹
	kerosene	1.5×10 ⁻¹¹
	hexamethyl-disilazane	2.9×10 ⁻¹¹
Low: conductivity greater than 5×10 ⁻¹¹	Jet-A fuel	2–3×10 ⁻¹¹
	gasoline	10 ⁻¹⁰
	turpentine	4×10 ⁻¹⁰
	crude oils	10 ⁻⁹ to 10 ⁻⁷
	halogenated hydrocarbons	10 ⁻⁸
	methyl alcohol	10 ⁻⁷
	ethyl alcohol	1.4×10 ⁻⁷
	cetones	10 ⁻⁵
	water: deionized	10 ⁻⁵
	iso-propanol	10 ⁻⁴
	water: acid rain	10 ⁻²

9.14.2.3.2 If the electrical potential difference between any part of the liquid surface and the metal tank shell should become high enough, the air above the liquid may become ionized and an arc may discharge to the shell. However, an arc to the tank shell is less likely than an arc to some projection or to a conductive object lowered into the tank. These projections or objects are known as spark (i.e., arc) promoters. No bonding or grounding of the tank or container can remove this internal charge.

9.14.2.3.3 If the tank or container is ungrounded, the charge can also be transmitted to the exterior of the tank and can arc to any grounded object brought into proximity to the now-charged tank external surface.

9.14.2.4* Switch Loading. *Switch loading* is a term used to describe a product being loaded into a tank or compartment that previously held a product of different vapor pressure and flash point. Switch loading can result in an ignition when a low vapor pressure/higher flash point product, such as fuel oil, is put into a cargo tank containing a flammable vapor from a previous cargo, such as gasoline. Discharge of the static normally developed during the filling can ignite the vapor-air mixture remaining from the low flash point liquid.

9.14.2.5 Spraying Operations. High-pressure spraying of ignitable liquids, such as in spray painting, can produce significant static electric charges on the surfaces being sprayed and the ungrounded spraying nozzle or gun.

9.14.2.5.1 If the material being sprayed can create an ignitable atmosphere, such as with paints utilizing flammable solvents, a static discharge can ignite the fuel-air mixture.

9.14.2.5.2 In general, high-pressure airless spraying apparatus have a higher possibility for creating dangerous accumulations of static than low-pressure compressed air sprayers.

9.14.2.6 Gases. When flowing gas is contaminated with metallic oxides or scale particles, with dust, or with liquid droplets or spray, static electric accumulations may result. A stream of particle-containing gas directed against a conductive object will charge the object unless the object is grounded or bonded to the liquid discharge pipe. If the accumulation of charge is sufficient, a static arc may occur. If the arc occurs in the presence of an ignitable atmosphere, an ignition may result.

9.14.2.7 Dusts and Fibers. Generation of a static charge can happen during handling and processing of dusts and fibers in industry. Dust dislodged from a surface or created by the pouring or agitation of dust-producing material, such as grain or pulverized material, can result in the accumulation of a static charge on any insulated conductive body with which it comes in contact. The minimum electrical energy required to ignite a dust cloud is typically in the range of 10 to 100 mJ. Thus, many dusts can ignite with less energy than might be expended by a static arc from machinery or the human body.

9.14.2.8 Static Electric Discharge from the Human Body. Numerous incidents have resulted from static electric discharges from people. The human body can accumulate an electric charge. The potential is greater in dry atmospheres than in humid atmospheres (see Table 9.14.2.8). If a person is insulated from ground, that person can accumulate a significant charge by walking on an insulating surface, by touching a charged object, by brushing surfaces while wearing nonconductive clothing, or by momentarily touching a grounded object in the presence of charges in the environment. During normal

activity, the potential of the human body can reach 10 kV to 15 kV, and the energy of a possible arc can reach 20 mJ to 30 mJ. By comparing these values to the minimum ignition energies (MIEs) of gases or vapors, the hazard is readily apparent.

9.14.2.9 Clothing. Outer garments can build up considerable static charges when layers of clothing are separated, moved away from the body, or removed entirely, particularly when of dissimilar fabrics. For some materials (particularly synthetic polymers) and/or low humidity conditions, an electrostatic charge may be accumulated. The use of synthetic fabrics and the removal of outer garments in ignitable atmospheres can become an ignition source.

9.14.3* Incendive Arc. An arc that has enough energy to ignite an ignitable mixture is said to be incendive. A nonincendive arc does not possess the energy required to cause ignition even if the arc occurs within an ignitable mixture. An ignitable mixture is commonly a gas, vapor of an ignitable liquid, or dust.

9.14.3.1 When the stored energy is high enough, and the gap between two bodies is small enough, the stored energy is released, producing an arc. The energy so stored and released by the arc is related to the capacitance of the charged body and the voltage in accordance with the following formula:

$$E_s = \frac{CV^2}{2} \quad [9.14.3.1]$$

where:

E_s = energy (J)

C = capacitance (F)

V = voltage (V)

9.14.3.2 Static arc energy is typically reported in thousandths of a joule (millijoules, or mJ).

9.14.3.3 Arcs Between Conductors. Arcs from ungrounded charged conductors, including the human body, are responsible for most fires and explosions ignited by static electricity. Arcs are typically intense capacitive discharges that occur in the gap between two charged conducting bodies, usually metal. The energy of an arc discharge is highly concentrated in space and in time.

Table 9.14.2.8 Electrostatic Voltages Resulting from Triboelectric Charging at Two Levels of Relative Humidity

Situation	Electrostatic Voltages (kV)	
	RH 10–20%	RH 65–90%
Walking across carpet	35	1.5
Walking over vinyl floor	12	0.25
Working at bench	6	0.1
Vinyl envelopes for work instructions	7	0.6
Poly bag picked up from bench	20	1.2
Work chair padded with polyurethane foam	18	1.5

9.14.3.3.1 The ability of an arc to produce ignition is governed largely by its energy, which will be some fraction of the total energy stored in the system.

9.14.3.3.2 To be capable of causing ignition, the energy released in the discharge must be at least equal to the minimum ignition energy (MIE) of the ignitable mixture. Other factors, such as the shape of the charged electrodes and the form of discharge, influence conditions for the static electric discharge and its likelihood of causing ignition.

9.14.3.4 Discharges Between Conductors and Insulators. Arcs often occur between conductors and insulators. Examples of such occurrences include situations in which plastic parts and structures, insulating films and webs, liquids, and particulate material are handled. The charging of these materials can result in surface discharges and sparks, depending on the accumulated charge and the shape of nearby conductive surfaces. The variable (both in magnitude and polarity) charge density observed on insulating surfaces is the effect of these discharges spreading over a limited part of the insulating surface.

9.14.4* Ignition Energy. The ability of an arc to produce ignition is governed largely by its energy and the minimum ignition energy of the exposed fuel. The energy of the static arc will necessarily be some fraction of its total stored energy. Some of the total stored energy will be expended in heating the electrodes. With flat plane electrodes, the minimum arc voltage to jump a gap (0.01 mm) is 350 V. Increased gap widths require proportionately larger voltages; for example, 1 mm requires approximately 4500 V.

9.14.4.1 Though as little as 350 V are required to arc across a small gap, it has been shown by practical and experimental experience that, because of heat loss to the electrodes, arcs arising from electrical potential differences of at least 1500 V are required to be incendive.

9.14.4.2 Dusts and fibers require a discharge energy of 10 to 100 times greater than gases and vapors for arc ignitions of optimum mixtures with air.

9.14.5 Controlling Accumulations of Static Electricity. A static charge can be removed or can dissipate naturally. A static charge cannot persist except on a body that is electrically insulated from its surroundings unless it is regenerated more rapidly than it is being removed.

9.14.5.1 Humidification. Many commonly encountered materials that are not usually considered to be electrical conductors — such as paper, fabrics, carpet, clothing, and cellulosic and other dusts — contain certain amounts of moisture in equilibrium with the surrounding atmosphere. The electrical conductivity of these materials is increased in proportion to the moisture content of the material, which depends on the relative humidity of the surrounding atmosphere.

9.14.5.1.1 Under conditions of high relative humidity, 50 percent or higher, these materials and the atmosphere will reach equilibrium and contain enough moisture to make the conductivity adequate to prevent significant static electricity accumulations. With low relative humidities of approximately 30 percent or less, these materials dry out and become good insulators, so static accumulations are more likely.

9.14.5.1.2 Materials such as plastic or rubber dusts or machine drive belts, which do not appreciably absorb water vapor, can

remain insulating surfaces and accumulate static charges even though the relative humidity approaches 100 percent.

9.14.5.1.3 The conductivity of the air itself is not appreciably increased by humidity.

9.14.5.2 Bonding and Grounding. Bonding is the process of electrically connecting two or more conductive objects. Grounding is the process of electrically connecting one or more conductive objects to ground potential and is a specific form of bonding.

9.14.5.2.1 A conductive object may also be grounded by being bonded to another conductive object that is already at ground potential. Some objects, such as underground metal pipe or large metal tanks resting on the earth, may be inherently grounded by their contact with the earth.

9.14.5.2.2 Bonding minimizes electrical potential differences between objects. Grounding minimizes potential differences between objects and the earth. Examples of these techniques include metal-to-metal contact between fixed objects and pickup brushes between moving objects and earth.

9.14.5.2.3 Investigators should not take the conditions of bonding or grounding for granted just by the appearance or contact of the objects in question. Specific electrical testing should be done to confirm the bonding or grounding conditions. Many factors, such as corrosion and earth settlement or shifting, can greatly affect the original state of the ground path.

9.14.5.2.4 If static arcing is suspected as an ignition source, examination and testing of the bonding, grounding, or other conductive paths should be made by qualified personnel using the criteria in NFPA 77.

9.14.6 Conditions Necessary for Static Arc Ignition. In order for a static discharge to be a source of ignition, five conditions must be fulfilled:

- (1) There must be an effective means of static charge generation.
- (2) There must be a means of accumulating and maintaining a charge of sufficient electrical potential.
- (3) There must be a static electric discharge arc of sufficient energy. (*See Section 19.3.*)
- (4) There must be a fuel source in the appropriate mixture with a minimum ignition energy less than the energy of the static electric arc. (*See Section 19.4.*)
- (5) The static arc and fuel source must occur together in the same place and at the same time.

9.14.7 Investigating Static Electric Ignitions. Often, the investigation of possible static electric ignitions depends on the discovery and analysis of circumstantial evidence and the elimination of other ignition sources, rather than on physical evidence of arcing.

9.14.7.1 In investigating static electricity as a possible ignition source, the investigator should identify whether or not the five conditions necessary for ignition existed.

9.14.7.2 An analysis must be made of the mechanism by which static electricity was generated. This analysis should include the identification of the materials or implements that caused the static accumulation, the extent of their electrical conductivity, and their relative motion, contact, and separation, or means by which electrons are exchanged.

9.14.7.3 The means of accumulating charge to sufficient levels where it can discharge in the form of an incendive arc should be identified. The states of bonding, grounding, and conductance of the material that accumulates the charge or to which the arc discharges should be identified.

9.14.7.4 Local records of meteorological conditions, including relative humidity, should be obtained and the possible influence on static accumulation or dissipation (relaxation) considered.

9.14.7.5 The location of the static electric arc should be determined as exactly as possible. In doing so, there is seldom any physical evidence of the actual discharge arc, if it occurred. Occasionally, there are witness accounts that describe the arc taking place at the time of the ignition. However, the investigator should attempt to verify witness accounts through analysis of physical and circumstantial evidence.

9.14.7.6 The investigator should determine whether the arc discharge could have been of sufficient energy to be a competent ignition source for the initial fuel.

9.14.7.7 The potential voltage and energy of the arc in relation to the size of the arc gap should be calculated to determine whether the incendive arc is feasible.

9.14.7.8 The possibility for the incendive arc and the initial fuel (in the proper configuration and mixture) to exist in the same place at the same time should be established.

9.14.8* Lightning.

9.14.8.1 General. Lightning is another form of static electricity in which the charge builds up on and in clouds and on the earth below. Movement of water droplets, dust, and ice particles in the violent winds and updrafts of a thunderstorm build up a polarized electrostatic charge in the clouds. When sufficient charge builds up, a discharge occurs in the form of a lightning strike between the charged cloud and objects of different potential. Lightning strikes may occur between clouds or between clouds and the earth. In the latter, charges of opposite polarity are generated in the cloud, while the charge in the ground below the cloud is induced by the cloud charge. In effect, the result is a giant capacitor, and when the charge builds up sufficiently, a discharge occurs.

9.14.8.2 Lightning Characteristics. Typical lightning channels have a core of energy plasma 12.7 mm to 19 mm (½ in. to ¾ in.) in diameter, surrounded by a 102 mm (4 in.) thick channel of superheated ionized air. Lightning return stroke currents average between 30,000 A and 45,000 A depending upon location, but can exceed 200,000 A. Potentials can range up to 15,000,000 V.

9.14.8.3 Lightning Strikes.

9.14.8.3.1 Lightning may strike any object that generates an upward-extending streamer that successfully connects with the downward extending step leader generated from the base of the cloud. In many cases, this may be the tallest object but could also be any protruding or elevated surface or mass. Lightning threats to a structure consist of the following:

- (1) A direct strike to the structure or an item attached to the structure, such as a TV antenna, air-conditioning unit, and so forth, extending up and out from the building roof

- (2) A strike near a structure that couples or channels energy onto energized or non-energized conductors
- (3) A direct strike to incoming conductors connected to the structure
- (4) A strike near overhead conductors that can couple lightning currents onto conductors connected to the structure

9.14.8.3.2 The bolt generally follows a conductive path to ground. At points along its path, the main bolt may divert, for example, from wiring to plumbing, particularly if underground water piping is used as a grounding device for the structure's electrical system.

9.14.8.4 Lightning Damage. Damage by lightning is caused by two characteristic properties: high currents and energy in a lightning strike and extremely high heat energy and temperatures generated in the channel by the electrical discharge. [See 9.14.8.4(A) through 9.14.8.4(D).]

(A) A tree can be shattered by lightning current conducted deep into the tree's heartwood with the heat vaporizing the moisture in the tree into steam—with explosive effects.

(B) Copper conductors not designed to carry the thousands of amperes of a lightning strike may be melted, severed, or completely vaporized by the overcurrent effect of a lightning discharge. Lightning currents may also generate overvoltages that trigger power system overcurrents sufficient to sever conductors in one or more locations. Copper and aluminum conductors properly sized and routed in accordance with NFPA 780 will not be damaged by a lightning impulse current up to 200,000 A.

(C) Where lightning strikes a steel-reinforced concrete building, the current may follow the steel reinforcing rods as the least resistive path. The high energy may destroy the surrounding concrete with explosive force to get to the reinforcing steel.

(D) Lightning can also cause fires by damaging fuel gas systems. Fuel gas appliance connectors have been known to have their flared ends damaged by electrical currents induced by lightning and other forms of electrical discharge. Where gas lines are damaged, fuel gas can leak, and the same arcing that caused the gas line to fail may also cause ignition of the fuel gas.

9.14.8.5 Lightning Detection Networks. Lightning detection networks exist that may assist in establishing time and location (to within 500 meters) of a lightning strike. Historical data is also available, including report of any lightning strikes detected within a specified time prior to a fire.

Δ 9.15 Batteries. Batteries are used for a wide variety of applications, including portable electronics, electric vehicles, uninterruptible power supplies, and energy storage systems. There are two types of batteries — primary and secondary. Primary batteries are discharged once and reach end of life, whereas secondary batteries can be discharged and recharged repeatedly. Batteries are produced in a variety of chemistries, each with their advantages and disadvantages. Common primary battery chemistries include alkaline, zinc-carbon, and lithium. Common secondary batteries include lead acid, lithium ion, nickel cadmium, and nickel metal hydride. Some battery chemistries are better suited for certain applications than others. Batteries are produced in a wide variety of designs and form factors, for example, battery cells can be interconnected in

series or parallel combinations to create a battery pack, which is housed in an enclosure that acts as a single unit. Depending on the chemistry and the materials used in the battery, remains of batteries may be found after a fire. They may be too damaged to indicate whether they provided power for ignition. However, what they were connected to could be important. A battery can provide enough power to ignite some materials under certain conditions. However, in most battery-powered devices circuitry or safety mechanisms should prevent the energy of the battery from being concentrated enough at one spot at one time to achieve ignition.

N 9.15.1 Lithium-ion Batteries. Lithium-ion batteries are increasingly used in portable electronics, electric vehicles, uninterruptible power supplies, and energy storage systems. Similar to other high-energy density fuel packages, when charged lithium-ion batteries are present during a fire they can serve as a fuel load whether they were involved in the cause of the fire or if they were attacked by a fire external to the battery. Investigators may need to seek assistance of subject matter experts to perform further analysis to determine if a fire-damaged battery was the cause of a fire. Several different lithium-ion chemistries are used with different inherent characteristics, but the investigator should be aware of certain characteristics that are common to most types.

N 9.15.1.1* State-of-Charge (SOC). The SOC is the level of charge of an electric battery relative to its capacity measured in percent charge. Batteries at higher SOC that ignite have a higher heat release rate compared to batteries at a lower SOC.

N 9.15.1.2 Protection Systems. Lithium-ion batteries typically have a battery management system (BMS) that manages the battery during charging and use. The BMS is intended to prevent the battery from operating outside its safe operating range (e.g., overcurrent, voltage, and temperature).

N 9.15.1.3 Impact or Abuse. Lithium-ion batteries can overheat and ignite if overcharged, undercharged, exposed to excessive heat or cold, flooded, short circuited, or physically damaged. Most commercially available batteries are tested against a number of abuse mechanisms as part of their certification process. Batteries at a higher SOC are more susceptible to failure due to external abuse.

N 9.15.1.4 Vent Gases. If a lithium-ion battery does fail catastrophically, products of partial combustion and flammable gases such as CO, CO₂, H₂, and light alkanes can be released. It is possible that other toxic gases can be released. The quantity and composition of vent gases will depend on the battery chemistry, capacity, SOC, and the environment where the battery is present.

N 9.15.1.5 Internal Resistance. Lithium-ion batteries typically exhibit low internal electrical resistance that can result in high short-circuit currents if the output leads are short circuited. However, protection mechanisms in the batteries may limit the duration of high current events.

N 9.15.1.6 Energy Provided to Ignition Source. The quantity of energy that lithium-ion battery packs or battery banks can provide to a potential ignition source at the fire origin point can be evaluated to determine if it is a competent ignition source.

Chapter 16 Documentation of the Investigation

16.1* Introduction.

16.1.1 The goal in documenting any fire or explosion investigation is to make an accurate recording of the investigation using media that will allow investigators to recall and communicate their observations at a later date. Common methods of accomplishing this goal include the use of photographs, video, diagrams, maps, overlays, audio recordings, laser surveys, digital and handwritten, notes, sketches, and reports.

16.1.2 Thorough and accurate documentation of the investigation is critical, because compilation of factual data is necessary to support and verify investigative opinions and conclusions. There are a number of resources to assist the investigator in documenting the investigation.

16.2 Photography.

16.2.1* General. The fire scene should be documented using still photography, which can be supplemented with video photography. Photographs are the most efficient and effective reminders of what the investigator saw while at the scene. Important items that were documented by photography may become more evident upon review of the photographs or videos. Photographs and video are necessary to substantiate the investigator's observations.

16.2.1.1* Photography and Videography. Investigators should be familiar with the photography and videography equipment and technology. Instruction and training in photography and videography can help familiarize the investigator with different photographic techniques and the capabilities of the equipment and technology.

16.2.1.2 Image Authentication. With digital images, as with film photographs, the tests of "a true and accurate representation" and "relevance to the testimony" must be met.

16.2.1.2.1 Digital images can be enhanced using available computer technology. Routine image enhancement can be used to correct brightness, color, and contrast. These enhancements were made by developers when film was the medium of choice. If an image has been enhanced, it is incumbent upon the investigator to preserve the original image and to document the extent to which the image was enhanced, should enhancement become an issue.

16.2.1.2.2* Steps should be taken to preserve the original image and establish a methodology to allow authentication. A procedure should be established for the secure storage of images (e.g., placement on an appropriate storage medium that will not allow them to be altered, or the utilization of a computer software program that does not allow the original image to be altered and saved using the original file name). Current imaging technology can track alterations of the original image and record any changes in the image's metadata (i.e., the image's digital file). The original photographs and the metadata should be secured and maintained.

16.2.2 Timing. Taking photographs or video during the fire or as soon as possible after a fire is important when documenting the fire scene, as the scene may become altered, disturbed, or even destroyed. Other situations where time is important include the following:

- (1) The building is in danger of imminent collapse or the structure must be demolished for safety reasons.

- (2) Hazardous materials or processes may create an imminent environmental hazard that needs immediate attention.
- (3) Evidence can be altered during overhaul and investigation. Evidence should be documented when discovered as layers of debris are removed. Documenting the layers can also assist in understanding the course of the fire.

16.2.3 Basics.

16.2.3.1 Types of Cameras. Digital equipment for stills and video has replaced film equipment as the technology of choice for scene documentation. There are many types of digital cameras available, from small, inexpensive point-and-shoot models to elaborate digital single lens reflex (dSLR) versions that can utilize a wide range of supplemental lenses and attachments. Most digital cameras offer a variety of automatic modes, which can be changed with manual adjustments for specific conditions (e.g., manual focus, macro mode, lighting).

16.2.3.1.1 Color Images. For fire scene- and investigation-related photography, color images are recommended.

16.2.3.1.2 Resolution. Resolution affects the useable size of an image. A lower resolution limits the size of an image for use as an exhibit at trial. Resolution is measured in pixels. The more pixels a camera has, the greater the detail it can capture and the larger the image that can be used for demonstrative purposes.

16.2.3.1.3 Number of Photographs Taken. As many photographs should be taken as are necessary to document and record the fire scene. Photographs should be taken of fire effects and fire patterns, observations, artifacts, and other items that may be of evidentiary value. The importance of taking enough photographs cannot be over-stated. The investigator should ensure that adequate photographic equipment is available prior to starting the investigation.

16.2.4 Understanding the Parts of a Camera.

16.2.4.1 Lenses. The camera lens is used to gather light and to focus the image. Most lenses are compound, meaning that multiple lenses are located in the same housing. The fire investigator needs a basic understanding of lens function to obtain quality photographs. The lens aperture is an adjustable opening that controls the amount of light admitted. The adjustments of this opening are sectioned into increments called f-stops. As the f-stop numbers increase, the size of the opening decreases, admitting less light. The higher the f-stop that can be used, the better the depth of field of the image. There is a trade-off between depth of field (f-stop) and adequate light (shutter speed). The photographer needs to balance the desire for more depth of field with the need for adequate light.

16.2.4.2 Focal Length. Digital cameras have variable or fixed focal length lenses that range from 20 mm to 1200 mm or greater. Some digital cameras are equipped with optical zoom (i.e., uses the lens), digital zoom (i.e., uses digital capture from lens image), or both. Macro lenses are useful for close-up photography. Investigators should determine the focal lengths they will use most often and become familiar with the abilities and limitations of the equipment.

16.2.4.3 Depth of Field. The area of clear definition, or depth of field, is the distance between the farthest and nearest objects that will be in focus at any given time. The depth of field depends on the distance to the object being photographed, the

lens opening, and the focal length of the lens being used. The depth of field will also determine the quality of detail in the investigator's images. For a given f-stop, the shorter the focal length of the lens, the greater the depth of field. For a given focal length lens, a larger f-stop (i.e., smaller opening) will provide a greater depth of field. If a fixed-lens camera is used, the investigator need not be concerned with adjustments, because the manufacturer has preset the lens. A recommended lens is a medium-range zoom, 20 mm to 80 mm depending on the size of the sensor, with a wide angle and a good depth of field and the ability to take close-ups.

16.2.4.4 Filters. The investigator should know that the use of colored filters is problematic. Unless the end results of colored filter use are known, it is recommended that they not be used. If colored filters are used, the investigator should take an image with a clear filter as well. An ultra-violet (UV) filter can be used continually as it reduces haze, improves contrast, and is a good means of protecting the lens.

16.2.4.5 Shutter Speed. The shutter speed is the amount of time the shutter remains open during an exposure. A minimum amount of light is needed for a good exposure. As the aperture is decreased (i.e., an increased f-stop), the amount of light admitted per unit time decreases, so a slow shutter speed is necessary. Shutter speeds below 1/60 sec (60) need the use of a tripod to avoid image blur.

16.2.5 Lighting. The most usable light source is the sun. No artificial light source can compare in terms of color, definition, and clarity. In low-light conditions, or where a burned area has poor reflective properties, a supplemental light source might be needed. Supplemental light can be obtained from a light source such as a floodlight, strobe, or flash unit.

16.2.5.1 Different light sources give off different color temperatures. Light emitted from an incandescent bulb has a different tint compared to that emitted from a fluorescent light. These different color temperatures are measured in Kelvin. Camera flashes are designed to simulate the color temperature of natural sunlight, which is 5500 Kelvin. The investigator should be aware of white balance and how to adjust their camera equipment. An auto-white balance or a flash-white balance setting is recommended for fire scene photography.

16.2.5.2 There are instances where the time period during which a photograph was taken will be important to understand what the photograph depicts. In photographs of an identical subject, natural lighting conditions that exist at noon can make a significant difference in a photographic image than natural lighting conditions that exist at dusk.

16.2.5.3 Flash units are necessary for the fire investigator's work. A removable flash unit that can be operated at an angle oblique to that of the lens view may be helpful. This practice is valuable in reducing the amount of reflection, obtaining a greater depth of field, and amplifying the texture of the heat- and flame-damaged surfaces.

16.2.5.4 The use of multiple flash units and remote operating devices called slaves can illuminate large areas.

16.2.5.5 For close-up work, a ring flash will reduce glare and give adequate lighting for the subject matter. The use of multiple flash units at oblique angles to the lens view will give a similar effect to the ring flash. A ring flash may in some cases "flatten" the image. This can be avoided by using multiple flashes, or by using a standard flash angled downward.

16.2.5.6 The investigator should ensure that glare from a flash or floodlight does not distort the actual appearance of an object. For example, smoke stains could appear lighter or nonexistent. In addition, shadows created could be interpreted as burn patterns. Video lighting can cause the same problems as still camera flash units. Using bounce flash, light diffusers, or other techniques may alleviate this problem.

16.2.5.7 The investigator concerned with the accurate exposure of a photograph can bracket the exposure. *Bracketing* is the process of taking the same subject matter at slightly different exposure settings to ensure at least one correct exposure. This is generally accomplished by taking a photograph at the recommended f-stop, another at one f-stop below, and another at one f-stop above. Some digital cameras are equipped with a special feature that will perform the bracketing function automatically when selected.

16.2.6 Special Types of Photography. Special types of photography, including infrared, x-ray, laser, panoramic, macro, high dynamic range, and microscopic photography, can be used under controlled circumstances. For example, laser photography can be used to document a latent fingerprint found on a body.

16.2.6.1 Composition and Techniques.

16.2.6.1.1 Photographs may be the most persuasive factor in the acceptance of the fire investigator's theory of the fire's evolution.

16.2.6.1.2 In fire investigation, photographs should be taken to portray the structure and contents that remain at the fire scene. The investigator should be aware that the order in which the photographs are taken is recorded in the metadata.

16.2.6.1.3 The investigator should document the entire fire scene and not just the hypothesized area(s) of origin, as it may be necessary to show the sequence of fire spread, the degree of smoke spread, evidence of undamaged areas, and evidence of alternative hypotheses.

16.2.6.2 Sequential Photographs. Sequential photographs, shown in Figure 16.2.6.2, are helpful in understanding the relationship of a small subject to its relative position in a known area. The small subject is first photographed from a distant position, where it is shown in context with its surroundings. Additional photographs are then taken increasingly closer until the subject is the focus of the entire frame.

16.2.6.3 Mosaic Photographs. Creating mosaic or panoramic photographs can be useful when a panoramic view is desired. A mosaic is created by physically assembling a number of photographs in overlay form to give a more-than-peripheral view of an area, as shown in Figure 16.2.6.3. The investigator needs to identify benchmark items about 1/3 of the image in from the edge of the view finder that will appear in the print and take the next photograph in the series with that same reference point on the opposite side of the view finder. The two or more individual prints can then be combined to obtain a wider view than the camera is capable of taking in a single shot. Many digital cameras have a preprogrammed feature that when selected, automatically adjusts the camera for taking a seamless panoramic image.

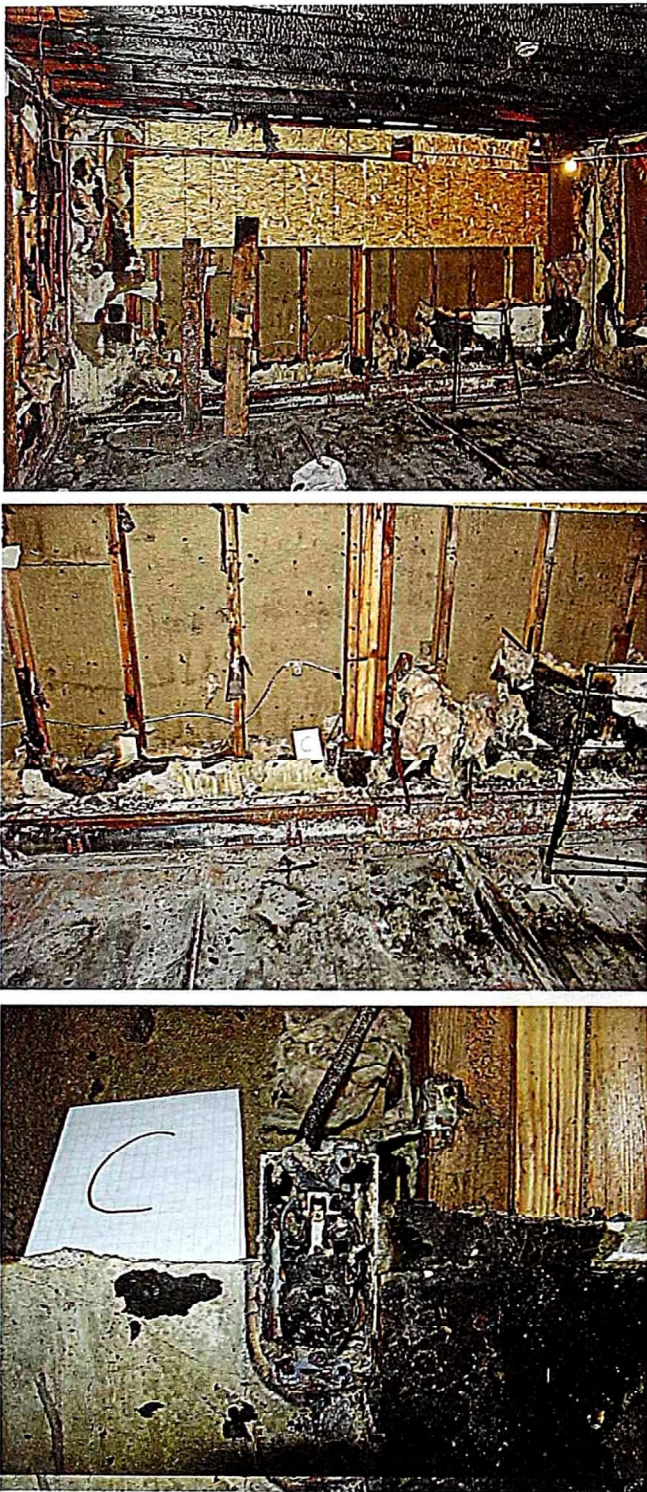


FIGURE 16.2.6.2 Sequential Photographs of an Outlet.

16.2.6.3.1 Digitally “Stitched” Mosaics. Digital stitching computer programs can create mosaic images from a series of digital photos. Many of these programs offer the ability to adjust and correct the brightness and contrast as well as the “fisheye lens” effect (i.e., aspect ratio) of the completed mosaic image. (See Figure 16.2.6.3.1.)

16.2.6.4 Photo Diagram. A photo diagram can be useful to the investigator. When the finished product of a floor plan is complete, it can be copied, and directional arrows can be drawn to indicate the direction the camera was pointed. The arrows are then labeled with numbers corresponding to the image they represent. This diagram will help orient viewers who are unfamiliar with the fire scene. A diagram prepared for a set of images might appear as shown in Figure 16.2.6.4. Recommended documentation includes identification of the photographer, identification of the fire scene (i.e., address or incident number), and the date that the photographs were taken. A title form can be used for the first image to record this photo documentation.

16.2.6.5 Assisting Photographer. If it is necessary for a person other than a fire investigator to take the photographs, the angles and composition should be supervised by the fire investigator to ensure that all of the appropriate photographs needed to document the fire are obtained. Investigators should communicate their needs to the photographer, as they may not have a chance to return to the fire scene. The investigators should not assume that the photographer understands what essential photographs are needed without discussing the content of each photo.

16.2.6.6 Photography and the Courts. For the fire investigator to weave photographs and testimony together in the courtroom, one requirement in all jurisdictions is that the photographs must be relevant to the testimony. Other requirements may exist depending upon the jurisdiction, including non-inflammatory content, clarity of the photograph, or lack of distortion. In most courts, if relevancy exists, the image will usually withstand objections.

16.2.7 Video. Video is a useful tool to the fire investigator. A great advantage to video is the ability to orient the fire scene by progressive movement of the viewing angle, linking together the use of the photo diagram, photo indexing, floor plan diagram, and still photos into a single operation. Digital video technology has advanced so much so that digital video capabilities are commonplace. Most digital cameras now provide the photographer with the ability to take both still photographs and video images, with many equipped to do both simultaneously.

16.2.7.1 The videographer’s movements should be at a slow pace. Excessive zooming and panning can have an adverse effect on the presentation of the video and should be avoided. It is recommended that the audio portion of the recording be muted during the videography of the scene.

16.2.7.2 Video can be used for documenting witness interviews, perspectives, activities, and locations.

16.2.7.3 Video recording of the fire scene can be used for documenting, fire patterns or artifact evidence, their location, and other important elements of the fire scene. The recording is not necessarily for the purpose of later presentation, but is simply another method by which the investigator can record and document the fire scene.

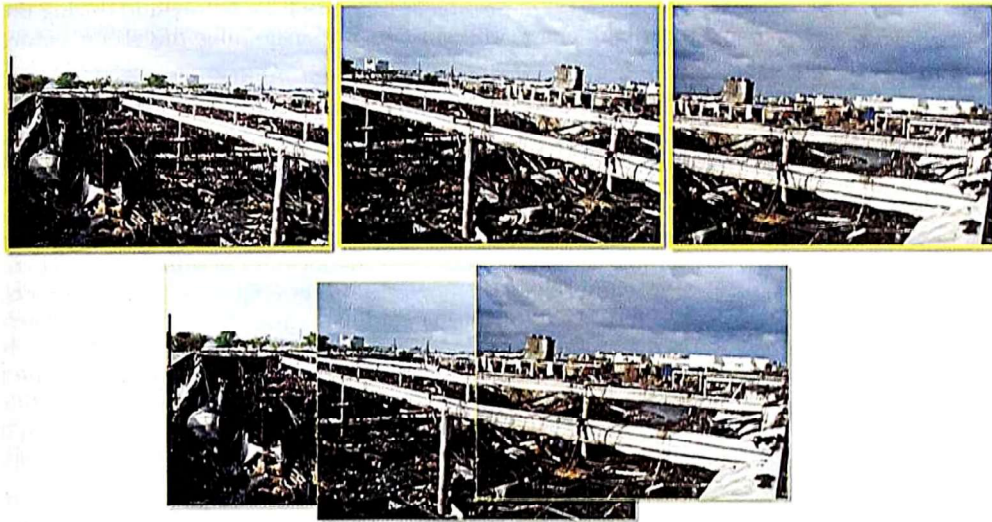


FIGURE 16.2.6.3 Three Individual Sequential Photographs of a Burned Wooden Pallet Factory (top), Made into a Physically Overlapped Mosaic (bottom).



FIGURE 16.2.6.3.1 Physically Overlapped Mosaic from Figure 16.2.6.3 (top) Compared to a Digitally Stitched Copy of the Mosaic (bottom).

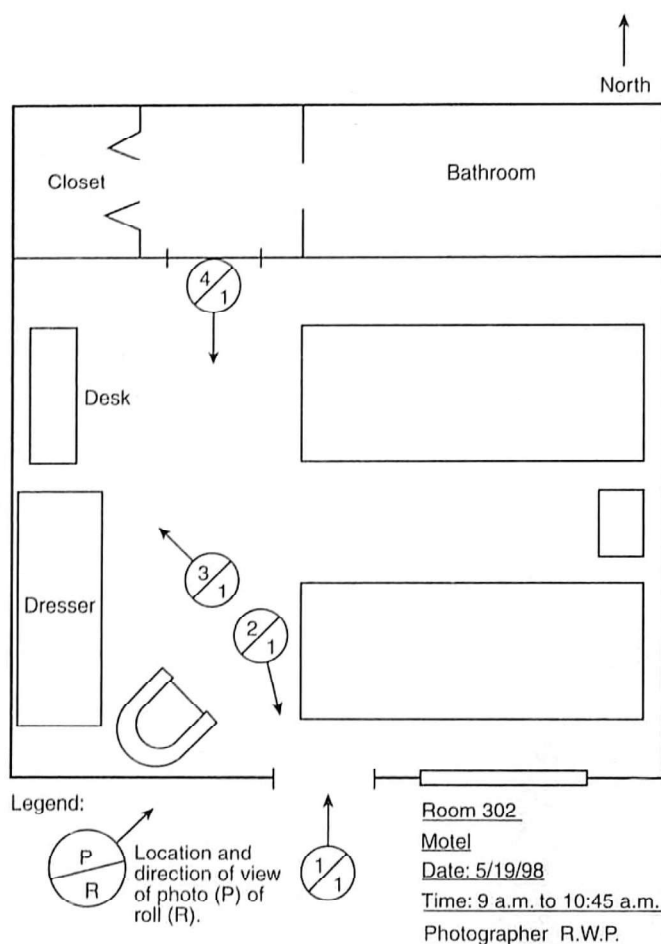


FIGURE 16.2.6.4 Diagram Showing Photo Locations.

16.2.7.4 Video recording can also be effective to document the examination of evidence, especially destructive examination. By video recording the examination, the condition and position of particular elements of evidence can be documented in real time.

16.2.7.5 The exclusive use of video is not recommended. Still photography remains the preferred method to visually document a fire scene investigation. Video should only be used in conjunction with and as a supplement to still photographs.

16.2.8 Suggested Activities to Be Documented. An investigation may be enhanced if as many aspects of the fire ground activities can be documented as possible or practical. Such documentation may include the condition of the scene upon arrival (i.e., with a dashboard camera), the suppression activities, overhaul, and the origin and cause investigation.

16.2.8.1 During the Fire. Photographs and video of the fire in progress should be taken if the opportunity exists. These help show the fire's progression as well as fire department operations. Fire suppression activities pertinent to the investigation include the operation of automatic systems as well as the activities of the responding fire services, such as hydrant locations, engine company positions, hose-lays, and attack line locations, all of which can play a role in the eventual outcome of the fire.

16.2.8.2 Overhaul Photographs. As the overhaul phase often involves moving the contents and sometimes structural

elements, when possible, photographing before and during the overhaul phase will assist in understanding the scene before the fire.

16.2.8.3 Bystander Photographs. Photographs of people in a crowd are often valuable for identifying individuals who may have additional knowledge that can be valuable to the overall investigation.

16.2.8.4 Exterior Photographs. A series of exterior shots should be taken to establish the location of a fire scene. These photographs could include street signs or access streets, numerical addresses, or landmarks that can be readily identified and are likely to remain for some time. Surrounding areas that would represent remote evidence, such as fire protection and exposure damage, should also be photographed. Exterior photographs should also be taken of all sides and corners of a structure to reveal all structural members and their relationships with each other. (See Figure 16.2.8.4.)

16.2.8.5 Structural Photographs. Structural photographs document the damage to the structure after heat and flame exposure. Structural photos can expose burn patterns that can track the evolution of the fire and can assist in understanding the fire's origin.

16.2.8.5.1 A recommended procedure is to include as much as possible with all exterior angles and views of the structure. Oblique corner photographs can give reference points for orientation. Photographs should show all angles necessary for a full explanation of a condition.

16.2.8.5.2 Photographs should be taken of structural failures such as windows, roofs, or walls, because such failures can change the route of fire travel and can play a significant role in the eventual outcome of the fire. Code violations or structural deficiencies should also be photographed because fire travel patterns may have resulted from those deficiencies.

16.2.8.6 Interior Photographs. Interior photographs are just as important. Lighting conditions will likely change from the exterior, calling for the need to adjust technique, but the concerns, such as tracking and documenting fire travel back-

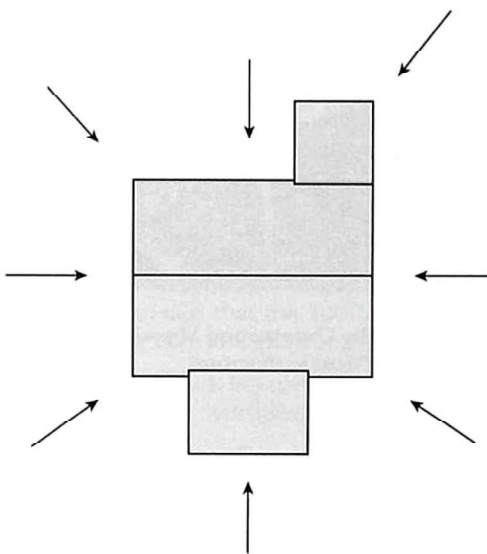


FIGURE 16.2.8.4 Photographing the Scene from All Angles and Corners.

ward toward the fire origin, are the same. Figure 16.2.8.6 provides a diagram of basic shots.

16.2.8.6.1 Rooms within the fire scene should be photographed, even if there is no damage. If warranted, closets and cabinet interiors should also be documented. In small buildings, this documentation could involve all rooms; but in large buildings, it may not be necessary to photograph all rooms unless there is a need to document the presence, absence, or condition of contents.

16.2.8.6.2 All heat-producing appliances or equipment, such as furnaces, within the fire scene should be photographed to document their role, if any, in the fire cause. The position of controls on those devices or equipment that are relevant to the investigation should be photographed. Likewise, all electrical cords and convenience outlets pertinent to the fire's location should be photographed.

16.2.8.6.3 All furniture and other contents within the fire scene should be photographed as found. Furniture and other contents involved and uncovered during the excavation and reconstruction should be photographed throughout the process and again after reconstruction. Protected areas left by any furnishings or other contents should also be photographed, as in the example shown in Figure 16.2.8.6.3.

16.2.8.6.4 The positions, conditions, and associated patterns of doors and windows should be documented.

16.2.8.6.5 Ventilation openings, whether existent pre- or post-incident, and associated patterns, should be documented.

16.2.8.6.6 Interior fire protection devices such as fire detection and alarm equipment, sprinklers, fire extinguishers, door closers, and dampers should be photographed.

16.2.8.6.7 Clocks may indicate the time power was discontinued to them or the time in which fire or heat physically stopped their movement. Caution must be used when interpreting battery-operated clocks as they may have stopped before the fire or continued to work after the fire.

16.2.8.7 Utility Photographs. The utility (e.g., gas, electric) entrances and controls both inside and outside a structure should be photographed. Photographs should include gas and electric meters, gas regulators, and their location relative to the structure. The electric utility pole equipped with the transformer serving the structure, the electrical service(s) coming into the structure, and the fuse or circuit breaker panels should also be photographed. Electrical circuit breaker panels, the position of all circuit breaker handles, and the panel's legend, when available, should be photographed.

16.2.8.8 Evidence Photographs. Items of evidentiary value should be photographed at the scene and can be re-photographed at the investigator's office or laboratory if a more detailed view is needed. During the excavation of the debris strata, articles in the debris may or may not be recognized as evidence. If photographs are taken in an archaeological manner, the location and position of evidence that can be of vital importance will be documented permanently. Photographs orient the articles of evidence in their original location as well as show their condition when found. In an evidentiary photograph, a ruler can be used to identify relative size of the evidence. Other items can also be used to identify the size of evidence as long as the item is readily identifiable and of constant size (e.g., a penny). A photograph should be taken of

the evidence without the ruler or marker prior to taking a photograph with the marker (*see 17.5.2.1*).

16.2.8.9 Victim Photographs. The locations of victims should be documented, and any evidence of actions taken or performed by those victims should be photographed. This documentation should include marks on walls, beds victims were occupying, or protected areas where a body was located. (*See Figure 16.2.8.9.*) If there is a death involved, the body should be photographed in place if possible. Surviving victims' injuries and their clothing worn should also be photographed.

16.2.8.10 Witness Viewpoint Photographs. During an investigation, if witnesses surface and give testimony as to what they observed from a certain vantage point, a photograph should be taken from the most identical view available. This photograph will orient all persons involved with the investigation, as well as a jury, to the direction of the witnesses' observations and could support or refute the possibility of their seeing what they said they saw.

16.2.8.11 Aerial Photographs. Views from an elevated vantage point, which can be an aerial fire apparatus, adjacent building, hill, or from an airplane, helicopter, or unmanned aircraft system (UAS), can often reveal fire spread patterns. It is suggested that the investigator seek the advice or assistance of an experienced aerial photographer when such photographs are desired. (*See Figure 16.2.8.11.*)

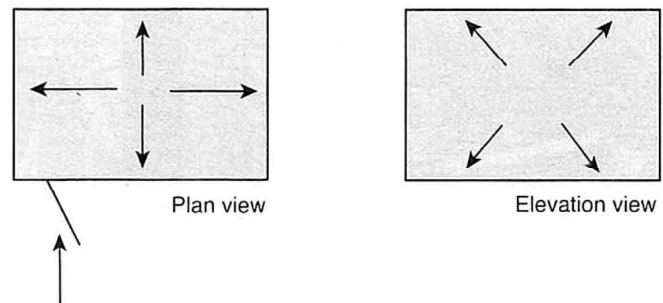


FIGURE 16.2.8.6 Photographing All Four Walls, the Floor, the Ceiling/Roof, and Both Sides of Each Door.

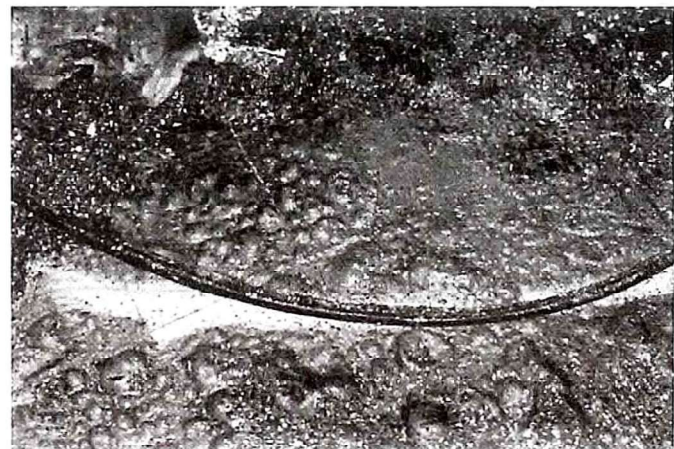


FIGURE 16.2.8.6.3 Floor Tile Protected from Radiant Heat by Wire.



FIGURE 16.2.8.9 Protected Area Where Body Was Located.



FIGURE 16.2.8.11 Aerial Overview of Fire Scene.

16.2.8.12 Satellite Imagery. Satellite imagery is available in many areas. One of its unique aspects is the possibility of both pre- and post-incident images. Depending on the satellite schedule, post-fire views may also be available. Many photos are available on the Internet. Internet searches, real estate web sites, and map sites may provide street views of the property and prefire imagery of the interior of the structure.

16.2.9 Photography Tips. The tips in 16.2.9.1 through 16.2.9.6 may assist or improve the investigator's ability to document a fire scene.

16.2.9.1 Upon arrival at a fire scene, a written "title sheet" that shows identifying information (i.e., location, date, or situational information) should be photographed.

16.2.9.2 The use of a tripod will allow for a more consistent mosaic photograph, reduce movement and blurred photographs, and assist in keeping the camera free of fire debris. A quick-release shoe on the tripod is recommended.

16.2.9.3 Extra batteries or battery packs should be kept or maintained, especially in cold weather where they can be

drained more quickly. Extended battery packs and batteries are available.

16.2.9.4 Batteries or battery packs should not be left in photography equipment for extended periods of time. Leaking batteries or damaged battery packs can cause a multitude of problems to sensitive computer, electrical and mechanical parts.

16.2.9.5 Obstruction of the flash or lens by hands, camera strap, or parts of the fire scene should be avoided.

16.2.9.6 Prior to leaving the scene, a final walk-through of the scene while reviewing the photographs taken can ensure that all necessary images have been recorded.

16.2.10* Presentation of Photograph. A variety of methodologies are available to the investigator for the presentation of reports, diagrams, and photographs. In deciding how to present photographs, the investigator should consider the following:

- (1) What method of presentation shows the image with the greatest clarity?
- (2) Will the image be used in an instructional format? If so, the investigator should follow guidelines for instructional aids.
- (3) What are the requirements of the agency or company requesting the investigation?
- (4) What are the requirements of the court where the photographs may be presented?

16.2.10.1 Computer-Based Presentations. Computer based presentation programs such as PowerPoint and Keynote are often used to present photographs, video, and other documentary evidence.

16.2.10.1.1 Computer-based presentations provide the user with the ability to put drawings and images on the same slide, as well as to provide other highlighting or information that may enhance the observer's ability to understand relationships or information being presented.

16.2.10.1.2 Prior to the presentation, the investigator should ensure that both the physical layout of the courtroom and the judge are amenable to such a presentation. Consideration should be given to the location of the screen and projector so that all parties can observe at the same time.

16.2.10.2 Hard Copy of Presentations. A hard copy of all material to be presented should be made available to all parties. Some courts will prohibit the investigator from introducing exhibits that have not been produced to all sides in accordance with local court rules. The investigator also needs a hard copy in case the presentation equipment fails.

16.3 Note Taking. Note taking is a method of documentation in addition to drawings and photographs. Items that may need to be documented in notes include the following:

- (1) Names and addresses
- (2) Model/serial numbers
- (3) Statements and interviews
- (4) Photo log
- (5) Identification of items (e.g., contents and furnishings)
- (6) Types and form of materials (e.g., wood paneling, foam plastic, carpet)
- (7) Data needed to produce an accurate computer model (*see Chapter 21*)

- (8) Investigator observations (e.g., fire effects and patterns, building conditions, position of switches and controls)

16.3.1 Forms of Incident Field Notes. The collection of data concerning an investigation is important in the analysis of any incident. The use of forms is not required in data collection; however, some forms have been developed to assist the investigator in the collection of data. These example forms and the information documented are not designed to constitute the report but instead provide a means to gather data that may be helpful in reaching conclusions so that a report can be prepared. (See A.16.3.2.)

16.3.2* Forms for Collecting Data. Some forms have been developed to assist the investigator in the collection of data. These forms and the information documented on them are not designed to constitute the incident report. They provide a means to gather data that may be helpful in reaching conclusions so that the incident report or the investigation report can be prepared. (See Table 16.3.2.)

16.3.3 Dictation of Field Notes. Many investigators dictate their notes using portable tape recorders or digital devices. Investigators should be careful not to rely solely on tape recorders or any single piece of equipment when documenting critical information or evidence.

16.3.4 The retention of original notes, diagrams, photographs, and measurements as detailed in Section 16.3 is the best practice. Unless otherwise required by a written policy or regulation, such data should be retained. These data constitute a body of factual information that should be retained until all reasonably perceived litigation processes are resolved. Information collected during the investigation may become significant long after it is collected and after the initial report is written. For example, notes or a diagram of a circuit breaker panel showing the status of the breakers may not be pertinent for a fire where the origin is in upholstered furniture, but may be of value regarding the status of the circuit powering a smoke alarm.

16.4 Diagrams and Drawings. Clear and concise sketches and diagrams can assist the investigator in documenting evidence of fire growth, scene conditions, and other details of the fire scene. Diagrams are also useful in providing support and understanding of the investigator's photographs. Diagrams may also be useful in conducting witness interviews. However, no matter how professional a diagram may appear, it is only as useful as the accuracy of the data used in its creation. Various types of drawings, including sketches, diagrams, and plans can be made or obtained to assist the investigator in documenting and analyzing the fire scene.

16.4.1 Types of Drawings. Fire investigations that can be reasonably expected to be involved in criminal or civil litigation should be sketched and diagrammed.

16.4.1.1 Sketches. Sketches are generally freehand diagrams or diagrams drawn with minimal tools that are completed at the scene and can be either three-dimensional or two-dimensional representations of features found at the fire scene.

16.4.1.2 Diagrams. Diagrams are generally more formal drawings that are completed after the scene investigation is completed. Diagrams are completed using the scene sketches and can be drawn using traditional methodologies or computer-based drawing programs. It should be noted that the completion of formal scene diagrams may not be required in some instances.

Table 16.3.2 Field Notes and Forms

Form	Purpose
Fire incident field notes	Any fire investigation to collect general incident data
Casualty field notes	Collection of general data on any victim killed or injured
Wildfire field notes	Data collection specifically for wildfire
Evidence form	Documentation of evidence collection and chain of custody
Vehicle inspection form	Data collection of incidents specifically involving motor vehicles
Photograph log	Documentation of photographs taken during the investigation
Electrical panel documentation	Collection of data specifically relating to electrical panels
Structure fire notes	Collection of data concerning structure fires
Insurance information	Documentation of insurance coverage for fire loss
Records/documents	Documentary records considered in the investigation
Compartment fire modeling	Collection of data necessary for compartment fire modeling

The decision to complete a more formal scene diagram will be determined by the investigator, agency policies, and scope of the investigation.

16.4.2 Selection of Drawings. It is recommended that original sketches and finalized diagrams be retained throughout the life of the investigation and any resulting litigation. See examples of various types of drawings in Figure 16.4.2(a) through Figure 16.4.2(f).

16.4.3 Drawing Tools and Equipment. Depending on the size or complexity of the fire, various techniques can be used to prepare the drawings. As with photographs, drawings are used to support memory, as the investigator may only get one chance to inspect the fire scene. As with the other methods of documenting the scene, the investigator will need to determine the type and detail of the diagrams developed and the type of drawings that may be requested from the building or equipment designer or manufacturer. During the course of the investigation, the investigator may have available a variety of drawings. These drawings may have been prepared by a building or equipment designer or manufacturer, may have been drawn by the investigator, or may have been developed by other investigators documenting conditions found at the time of their investigation.

16.4.3.1 Computer software is available that allows the investigator to prepare high-quality diagrams from scene-generated sketches. The fire investigator should look to several features in deciding on the best computer drawing tool to meet the intended goals. The fire investigator must first decide whether or

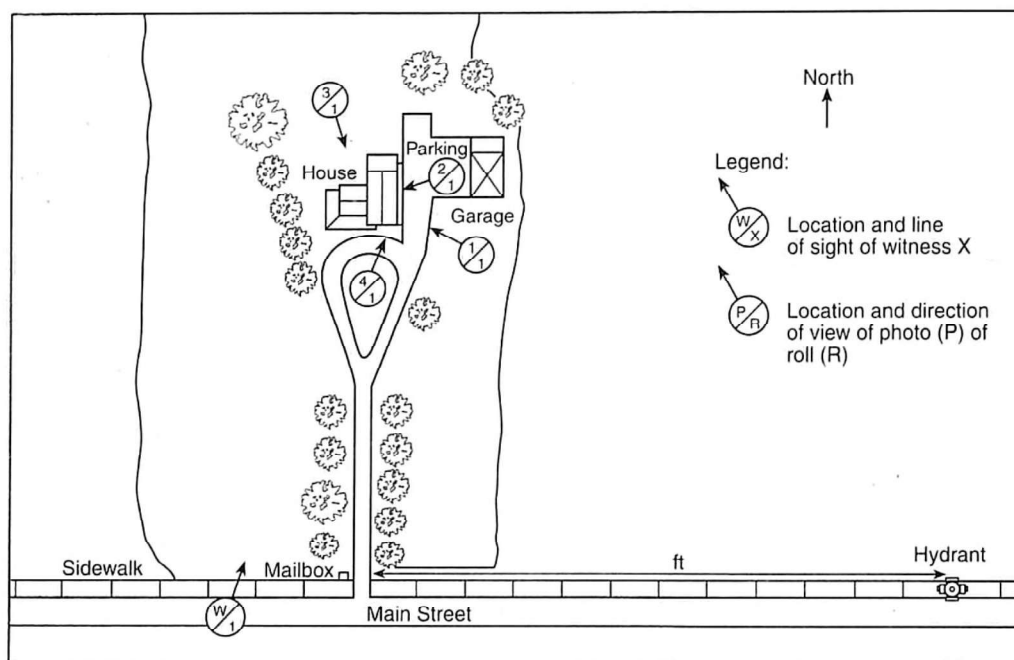


FIGURE 16.4.2(a) Site Plan Showing Photo and Witness Locations.

not three-dimensional (3D) capability is required. In making that decision, the fire investigator must also decide whether or not the time invested in learning the package and additional complexity warrant the investment in such a tool. However, 3D drawings can yield great benefits in the investigation in determining and demonstrating such issues as the physical interrelationships of building components or the available view to witness. Regardless of the package selected, the most important criterion is the fire investigator's ability to create, modify, produce output, and manipulate a drawing within the selected package. Another consideration would be the compatibility of the Computer Aided Drawing (CAD) output to provide computer fire models input.

16.4.3.2 A good drawing package should also allow for the drawing on separate "layers" that can be turned on and off for different display purposes, such as prefire layout and post-fire debris. The package should also provide for automatic dimensioning and various dimensioning styles (i.e., decimal 1.5 ft, architectural 1 ft 6 in., and 457 mm). The package should also come with a wide variety of dimensioned "parts libraries." This component of the package provides the predrawn details, such as kitchen and bathroom fixtures, for placement by the investigator in the drawing.

16.4.4 Diagram Elements. The investigator, depending on the scope and complexity of the investigation, and on agency procedures, will decide on what elements to include on sketches and diagrams; however, there are a number of key elements that should be on all sketches and diagrams, as outlined in 16.4.4(A) through 16.4.4(D).

(A) General Information. Identification of the individual who prepared the diagram, diagram title, date of preparation, and other pertinent information should be included.

(B) Identification of Compass Orientation. Identification of compass orientation should be included on sketches and diagrams of fire scenes.

(C) Scale. The drawing should be drawn approximately to scale. The scale should be identified or indicated "Approximate Scale" or "Not to Exact Scale," and a graphic scale or approximate scale may be provided on the drawing.

(D)* Symbols. Symbols are commonly utilized on sketches and drawings to denote certain features; for example, a door symbol is used to indicate that there is a door in the wall and is drawn in the direction of swing. To facilitate understanding, it is recommended that the investigator utilize standard drawing symbols commonly found in the architectural or engineering community. For fire protection symbols, the investigator may utilize the symbols contained in NFPA 170.

(E) Legend. If symbols are utilized that are not readily identifiable, the investigator should use a legend on the drawing to eliminate the potential for confusion as to what the symbol represents.

16.4.5 Drawings. Generally, a simple sketch of the room of origin or immediate scene should be prepared and should include items such as furniture, windows and doors, and other useful data. A typical building sketch can show the relative locations of rooms, stairs, windows, doors, and associated fire damage. These drawings can be done freehand with approximate dimensions. This type of drawing should suffice on fire cases where the fire analysis and conclusions are simple. More complex scenes or litigation cases will often require developing or acquiring actual building plans and detailed documentation of construction, equipment, furnishings, witness location, and damage.

16.4.5.1 Site or Area Plans. Plot or area diagrams may be needed to show the placement of apparatus, the location of the fire scene to other buildings, water supplies, or similar information. Diagrams of this nature assist in documenting important factors outside of the structure. See Figure 16.4.2(a).

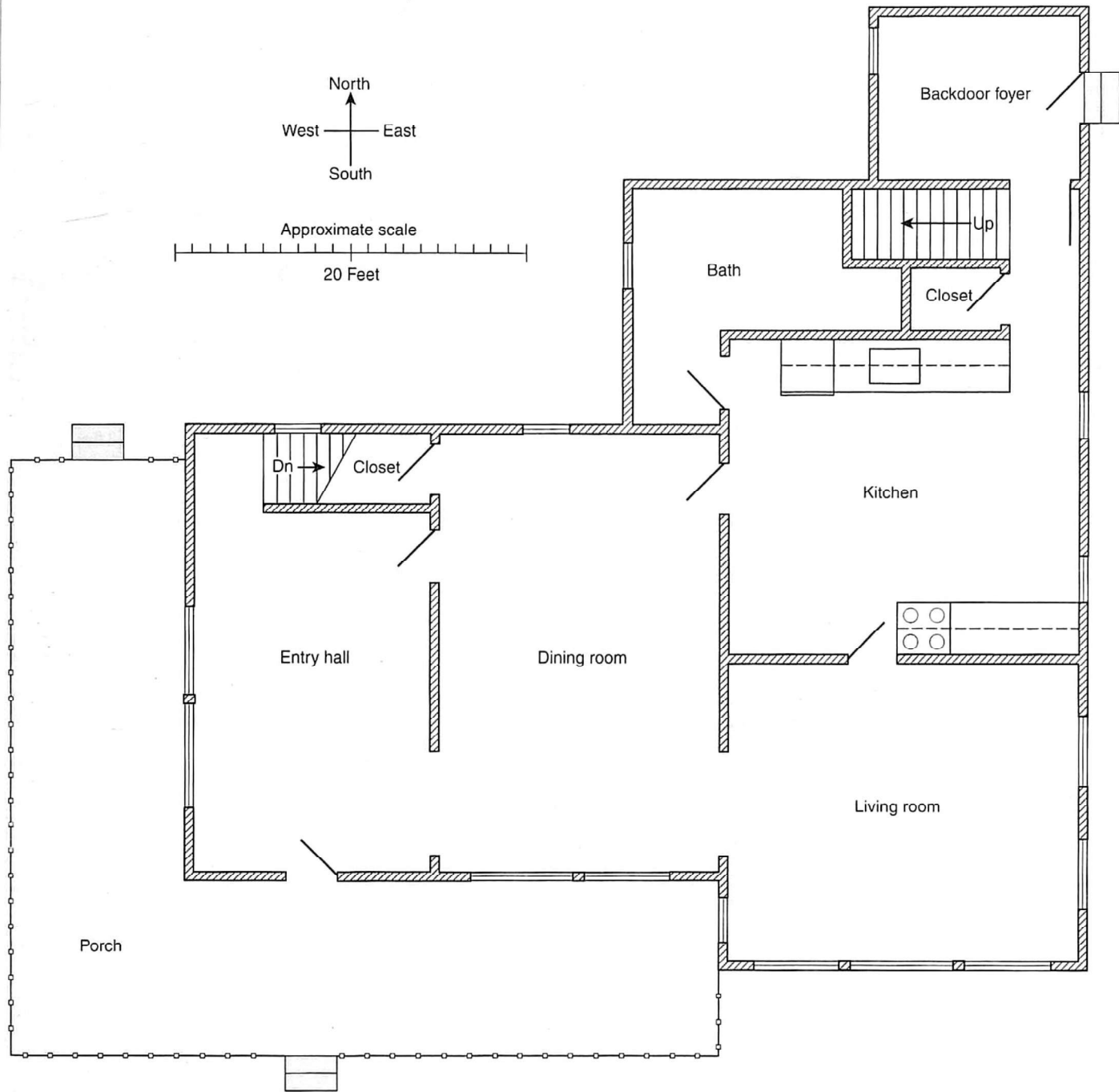
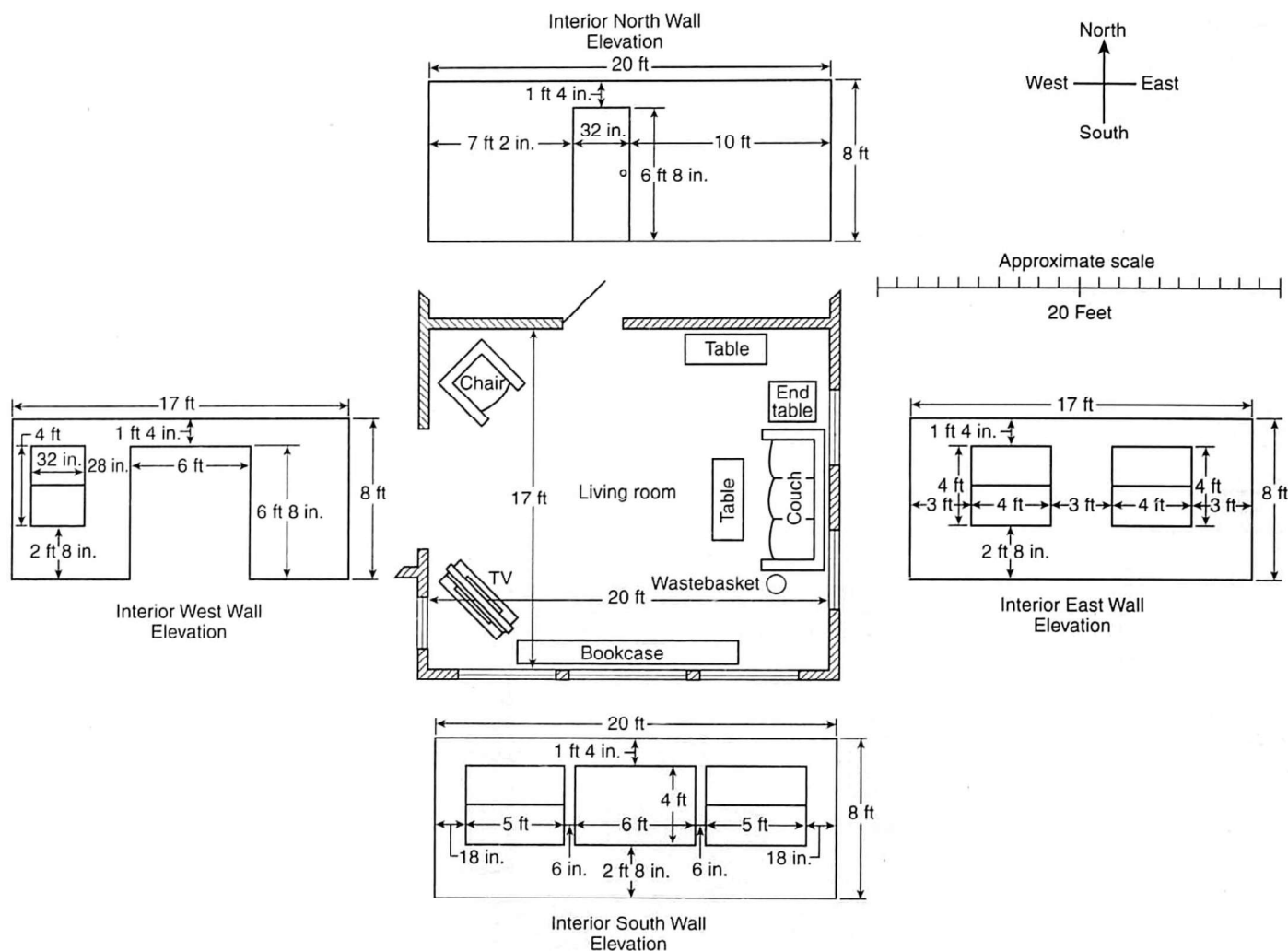


FIGURE 16.4.2(b) Detailed Floor Plan.



△ FIGURE 16.4.2(c) Diagram of Room and Contents Showing Dimensions.

16.4.5.2 Floor Plans. Floor plans of a building identify the locations of rooms, stairs, windows, doors, and other features of the structure. See Figure 16.4.2(b).

16.4.5.3 Elevations. Elevation drawings are single plane diagrams that show a wall, either interior or exterior, and specific information about the wall. See elevation portion of Figure 16.4.5.3.

16.4.5.4 Details and Sections. Details and sections are drawn to show specific features of an item. There is a wide variety of information that can be represented in a detail or section diagram, such as the position of switches or controls, damage to an item, location of an item, construction features, and many more.

16.4.5.5 Exploded View Diagrams. Exploded view diagrams are often used to show assembly of components or parts lists. The investigator may also utilize this format to show all surfaces inside of a room or compartment on the same diagram. See Figure 16.4.2(d).

16.4.5.6* Three-Dimensional (3D) Representations. In many cases, it may be necessary for the investigator to obtain sufficient dimensional data to develop a 3D representation of the

fire scene. Various 3D tools can assist fire and explosion investigators in providing accurate 3D representations of the scene in advance of a fire or explosion, during an active incident, and for post incident analysis. These tools include the use of photogrammetry, total stations, and high-definition laser scanning (HDS LiDAR). The 3D scene or "model" provides new opportunities for investigators to test hypotheses via witness viewpoints, computational fluid dynamics, and a true color, true scale, and sharable virtual scene. Three D data capture techniques provide a way to document perishable evidence, spatial relativity of fuels, compartments, and ventilation openings and flow paths.

16.4.5.6.1 Structural Dimensions. The investigator should measure and document dimensions that would be needed to develop an accurate 3D representation of the structure, as illustrated in Figure 16.4.2(c). Consideration should be given to the documentation of such often overlooked dimensions as the thickness of walls, air gaps in doors, and the slope of floors, walls, and ceilings. Such representative geometry may be needed if subsequent fire modeling and/or experimental tests are conducted as part of the incident investigation.

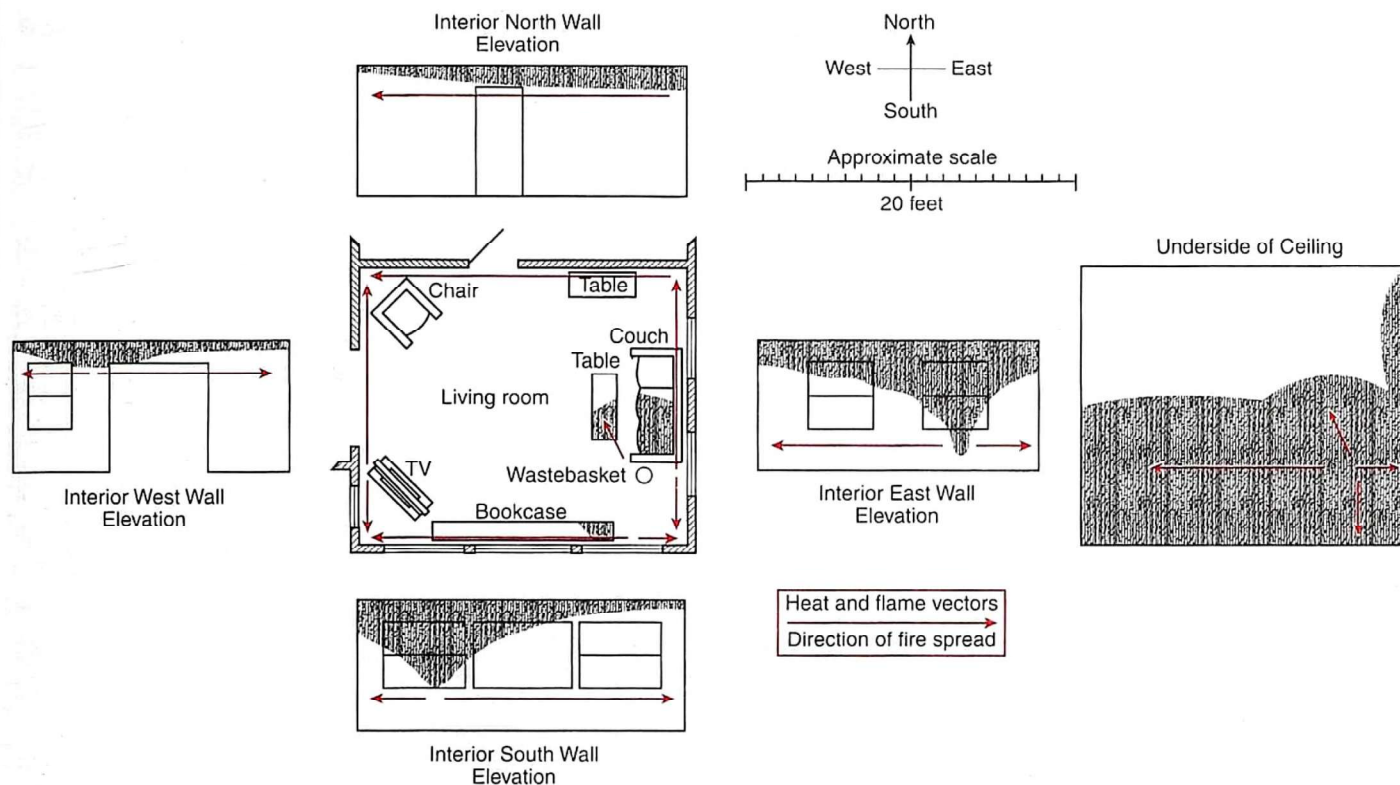


FIGURE 16.4.2(d) Exploded Room Diagram Showing Damage Patterns, Sample Locations, and Photo Locations.

16.4.5.6.2 Availability of Dimensional Data. While dimensional data may be found in building plans, layouts, or as-built drawings, it may not be known at the time of the scene investigation if such sources of information exist, especially in the case of older structures. Thus, it is prudent for the investigator to collect the physical dimensions independent of the existence of plans, layouts, or drawings.

16.4.5.7 Specialized Fire Investigation Diagrams.

16.4.5.7.1 In addition to a basic floor plan diagram, it is recommended that the fire investigator utilize specialized sketches and diagrams to assist in documenting specifics of the fire investigation. The decision to utilize these or other specialized sketches and diagrams is dependent on the decision of the investigator and the need to represent a complex fact or issue. These types of specialized investigation diagrams will include electrical, mechanical, process system, and fuel gas piping schematics, fire pattern, depth of char survey, depth or calcination survey, witness line of sight, heat and flame vector analysis, and others, as required.

16.4.5.7.2 The use of a computer-drawing program facilitates the development of many different specialized drawings from the initial floor plan. The use of layers or overlays can assist in the understanding of specific features and prevent the drawing from becoming overly complicated.

16.4.6 Prepared Design and Construction Drawings.

16.4.6.1 General. Prepared design and construction diagrams are those diagrams that were developed for the design and construction of buildings, equipment, appliances, and similar items by the design professional. These diagrams are often

useful to the investigator to assist in determining components, design features, specifications, and other items.

16.4.6.1.1 The availability and complexity of prepared design and construction drawings will vary, depending on the type and size of the occupancy for structures or the ability to identify a specific manufactured item.

16.4.6.1.2 During or after building construction or as a result of occupancy changes, modifications may occur. These modifications may not be reflected on any existing drawings. When using prepared building diagrams, the investigator will need to compare the drawing to the actual building layout.

16.4.6.2 Architectural and Engineering Drawings. Within the design and construction process, there are several types of drawings with which the investigator should be familiar. The most common drawings along with the discipline that generally prepares them are shown in Table 16.4.6.2.

16.4.6.3 Architectural and Engineering Schedules. On larger projects, it may be necessary to detail the types of equipment in lists that are called *schedules*. Where many components are specified in great detail, a schedule will usually exist. Typical schedules are as follows:

- (1) Door and window schedule
- (2) Interior finish schedule
- (3) Electrical schedule
- (4) HVAC schedule
- (5) Plumbing schedule
- (6) Lighting schedule

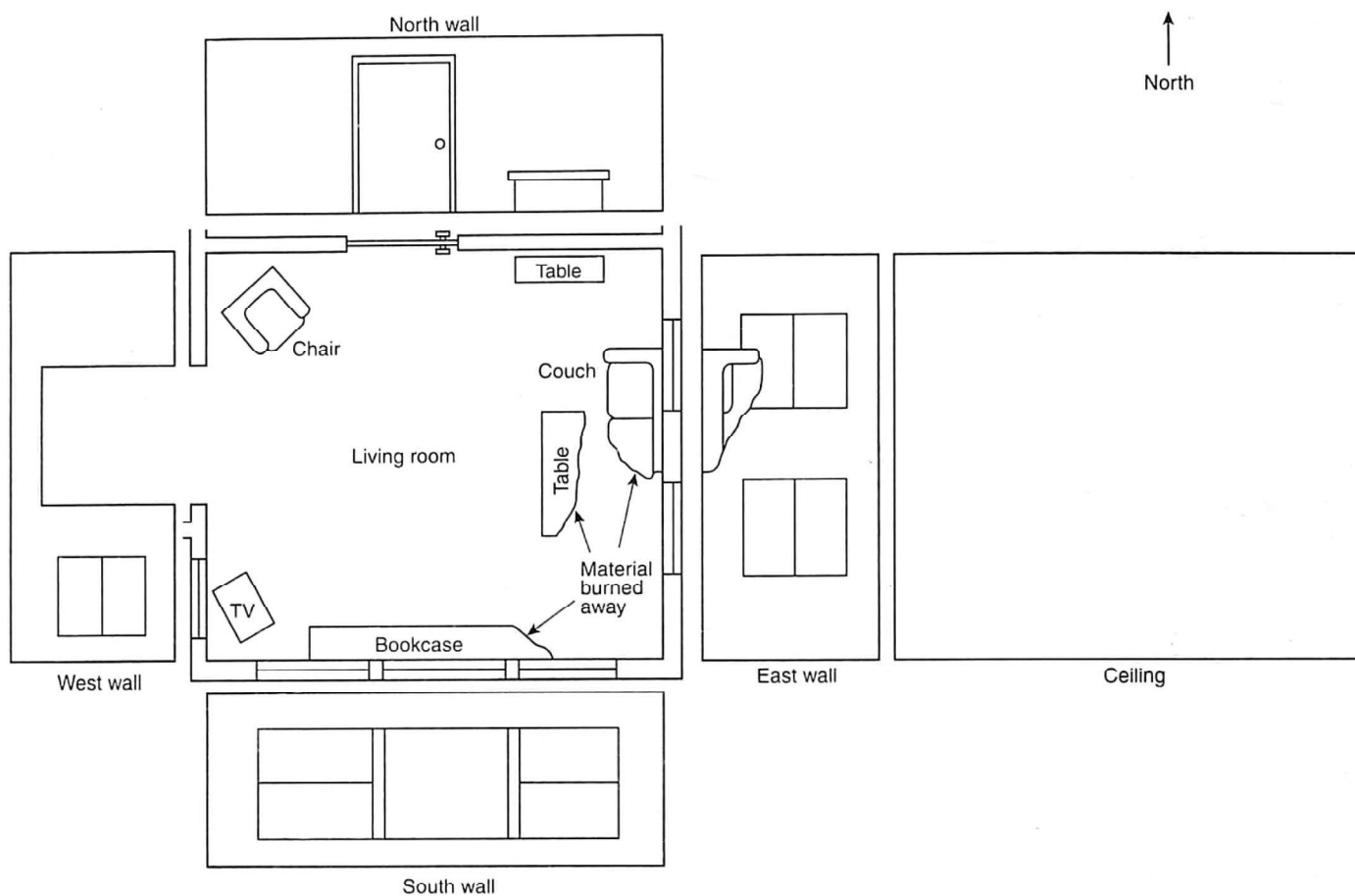
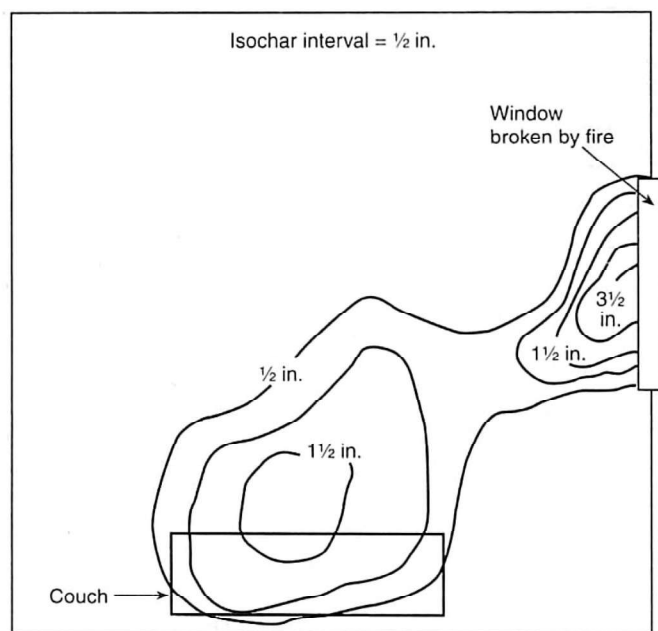


FIGURE 16.4.2(e) Contents Reconstruction Diagram Showing Damaged Furniture in Original Positions.



For SI units, 1 in. = 25.4 mm.

FIGURE 16.4.2(f) An Isochar Diagram Showing Lines of Equal Char Depth on Exposed Ceiling Joists.

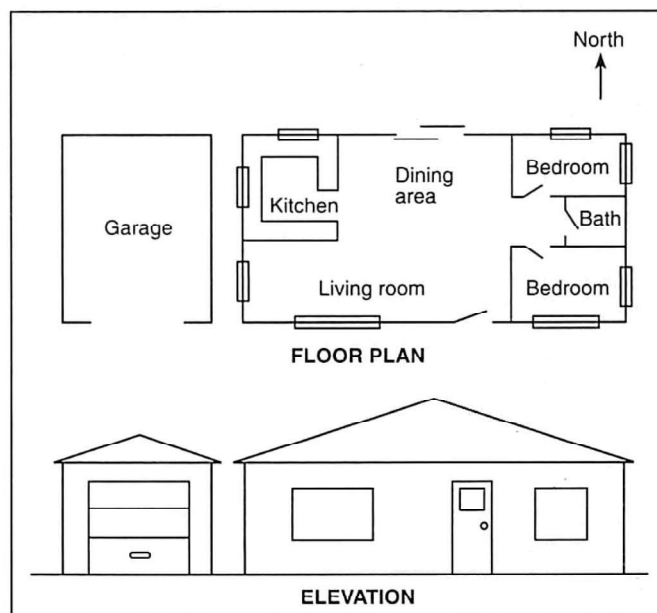


FIGURE 16.4.5.3 Minimum Drawing for Simple Fire Analysis.

Table 16.4.6.2 Design and Construction Drawings That May Be Available

Type	Information	Discipline
Topographical	Varying grade of the land	Surveyor
Site plan	Structure on the property with sewer, water, electrical distributions to the structure	Civil engineer
Floor plan	Walls and rooms of structure as if you were looking down on it	Architect
Plumbing	Layout and size of piping for fresh water and wastewater	Mechanical engineer
Electrical	Size and arrangement of service entrance, switches and outlets, fixed electrical appliances	Electrical engineer
Mechanical	HVAC system	Mechanical engineer
Sprinkler/ fire alarm	Self-explanatory	Fire protection engineer
Structural	Frame of building	Structural engineer
Elevations	Shows interior/exterior walls	Architect
Cross-section	Shows what the inside of components look like if cut through	Architect
Details	Show close-ups of complex areas	All disciplines

16.4.6.4* Specifications. Architects and engineers prepare specifications to accompany their drawings. While the drawings show the geometry of the project, the specifications detail the quality of the materials, responsibilities of various contractors, and the general administration of the project. Specifications are usually divided into sections for the various components of the building. For the fire investigator, the properties of materials can be identified through a specification review and may assist in the analysis of the fire scene.

16.4.6.5 Appliances and Building Equipment. Parts diagrams and shop drawings may be available for appliances and equipment that may have been involved in a fire scenario. These diagrams may assist the investigator in determining or obtaining specific information about components or other features.

16.5* Reports and Testimony. The decisive step in the documentation of the investigation may be the preparation and submittal of a report. The format and content of the report will depend in part on the needs of the organization or client on whose behalf the investigation was performed. When the investigator's role is that of an expert witness, it will also depend on the legal requirements for expert reports or testimony in the specific jurisdiction or court where the case is pending. Because of the variability of these requirements, no report format is prescribed here. For guidance on court-mandated reports, see Chapter 12. An investigator's reports and testimony are inherently linked. Whether an investigator is providing testimony as an expert, as a layperson acting as a fact witness, or both, the investigator's report usually provides the foundations for an investigator's testimony. To the extent that this section addresses how an expert's opinions should be expressed, it deals with both reporting and testimony.

16.5.1 Purpose of Reports. The purpose of a written report is to document an accurate reflection of the investigator's obser-

vations, activities, analyses, and conclusions. The report should contain facts and data that the investigator relied upon to reach any opinions or conclusions. The report should also contain the investigator's reasoning of how each opinion was reached. Reports may be used for improvement of public safety, prevention of similar future incidents, the basis for criminal or civil litigation, the basis for insurance claims, or simply documentation of the facts for the record. (*See NFPA 1033.*)

16.5.2 Report Organization and Content. The investigator should develop and organize a report to provide the desired information of the party requesting the report. The investigator should know that satisfying the requestor of the report with a preliminary or cursory report may not meet the requirements or the needs of a jurisdiction, court, or NFPA 1033.

16.5.3 Descriptive Information. The following information is usually found in a report:

- (1) Date the report was submitted
- (2) Date, time, and location of incident
- (3) Date and location of examination(s)
- (4) Name of the person or entity requesting the report
- (5) The scope of the investigation (i.e., tasks assigned and tasks completed)
- (6) Nature of the report (e.g., preliminary, interim, final, summary, supplementary)
- (7) Name of person(s) preparing the report

16.5.4 Opinions and Conclusions. The report should contain the investigator's opinions and conclusions in a clear, delineated section, whether at the beginning or the end of the report. The reader should not have to search the report looking for opinions and conclusions in a narrative or analysis section. The report should also state the basis or bases for each opinion and conclusion, including alternative hypotheses that were considered. The name, address, and affiliation of each person who

Chapter 17 Physical Evidence

17.1* General. During the course of any fire investigation, the fire investigator is likely to be responsible for locating, collecting, identifying, storing, examining, and arranging for testing of physical evidence. The fire investigator should be thoroughly familiar with the recommended and accepted methods of processing such physical evidence.

17.2 Physical Evidence.

17.2.1 Physical evidence, defined generally, is any physical or tangible item that tends to prove or disprove a particular fact or issue. Physical evidence at the fire scene may be relevant to the issues of the origin, cause, spread, or the responsibility for the fire.

17.2.2* The decision on what physical evidence to collect at the incident scene for submission to a laboratory or other testing facility for examination and testing, or for support of a fact or opinion, rests with the fire investigator. This decision may be based on a variety of considerations, such as the scope of the investigation, legal requirements, or prohibition. (See Section 14.2.) Additional evidence may also be collected by others, including other investigators, insurance company representatives, manufacturer's representatives, owners, and occupants. The investigator should also be aware of standards and procedures relating to evidentiary issues and those issues related to spoliation of evidence.

17.3* Preservation of the Fire Scene and Physical Evidence.

17.3.1 General. Every attempt should be made to protect and preserve the fire scene, because evidence could be easily destroyed or lost in an improperly preserved fire scene.

17.3.1.1 Generally, the cause of a fire or explosion is not known until near the end of the investigation. Therefore, the evidentiary or interpretative value of various pieces of physical evidence observed at the scene may not be known until, at, or near the end of the fire scene examination, or until the end of the complete investigation. As a result, the entire fire scene should be considered physical evidence and should be protected and preserved. Consideration should be given to temporarily placing removed ash and debris into bags, tarps, or other suitable containers labeled as to the location from which it was removed. This way, if components from an appliance or an incendiary device are found to be missing they can be more easily found in a labeled container.

17.3.1.2 The responsibility for the preservation of the fire scene and physical evidence does not lie solely with the fire investigator, but should begin with arriving firefighting units or police authorities. Lack of preservation may result in the destruction, contamination, loss, or unnecessary movement of physical evidence. Initially, the incident commander and, later, the fire investigator should secure or ensure the security of the fire scene from unnecessary and unauthorized intrusions and should limit fire suppression activities to those that are necessary.

17.3.1.3 Evidence at the fire scene should be considered not only in a criminal context, such as in traditional forensic evidence (e.g., weapons, bodily fluids, footprints), nor should it be limited to arson-related evidence, items, or artifacts, such as incendiary devices or containers. Potential evidence at the fire scene and surrounding areas can include the physical struc-

ture, the contents, the artifacts, and any materials ignited or any material on which fire patterns appear.

17.3.2 Fire Patterns as Physical Evidence. The evidentiary and interpretative use of fire patterns may be valuable in the identification of a potential ignition source, such as an incendiary device in an arson fire or an appliance in an accidental fire. Fire patterns are the visible or measurable physical effects that remain after a fire. These include thermal effects on materials, such as charring, oxidation, consumption of combustibles, smoke and soot deposits, distortion, melting, color changes, changes in the character of materials, structural collapse, and other effects. (See Section 6.3.)

17.3.3 Artifact Evidence. Artifacts can be the remains of the material first ignited, the ignition source, or other items or components in some way related to the fire ignition, development, or spread. An artifact may also be an item on which fire patterns are present, in which case the preservation of the artifact is not for the item itself but for the fire pattern that is contained thereon.

17.3.4 Protecting Evidence.

17.3.4.1 There are a number of methods that can be utilized to protect evidence from destruction. Some methods include posting a firefighter or police officer as a sentry to prevent or limit access to a building, a room, or an area; use of traffic cones or numerical markers to identify evidence or areas that warrant further examination; covering the area or evidence with tarpaulins prior to overhaul; or isolating the room or area with rope, caution tape, or police line tape. The investigator may benefit from supervising overhaul and salvage operations.

17.3.4.2 Items found at the fire scene, such as empty boxes or buckets, may be placed over an artifact. However, these items may not clearly identify the artifact as evidence that should be preserved by firefighters or others at the fire scene. If evidence is not clearly identified, it may be susceptible to movement or destruction at the scene.

17.3.4.3 Flag, Bag, Tag. During the examination of the scene it can be useful to identify, protect, and mark items of interest or items that could be potential evidence. Such marking can alert investigators to those items of interest and begin the documentation process.

17.3.4.3.1 Flag. The utilization of inexpensive plastic flagging to identify items or areas of interest to protect can aid the ongoing investigation. The flagging alerts others on-scene not to disturb or remove those items. Marking the items of interest can be especially important when using heavy equipment or assistants who are not fire investigators. Different colors of flagging can be used to identify items such as electrical wiring or gas lines. The bright colors also help identify those items when taking photographs, especially large-scale photographs used to show the layout of such utilities. The use of the flagging starts with the initial walk-through of the scene and continues through reconstruction of the contents in the area of origin.

17.3.4.3.2 Bag. Items of unknown evidentiary value are frequently located during the scene examination. Bagging can assist preservation of those items. The item of interest should be documented in place and then can be placed in a plastic bag (or other appropriate container). This can be especially important if an item contains small or fragile pieces that might be further disturbed during the normal scene examination process. In some cases the debris in the immediate area of the

item could be placed into separate containers for later, closer examination. The item can be left in place in case it is needed as evidence or to assist other investigators who may later examine the scene. If the item is later needed as evidence, it has been preserved in place and can be collected using the normal evidence collection procedures.

17.3.4.3.3 Tag. During the course of normal scene examination it may be necessary to move items from their original position. The investigator can tag those items, noting information of importance such as location, orientation, or alteration. The tagging can assist later reconstruction of the scene contents or investigators who later examine the scene, or if the item is later collected as evidence.

17.3.5 Role and Responsibilities of Fire Suppression Personnel in Preserving the Fire Scene.

17.3.5.1 Generally, fire officers and firefighters have been instructed during basic fire training that they have a responsibility at the fire scene regarding fire investigation.

17.3.5.1.1 In most cases, this responsibility is identified as recognizing the indicators of incendiary fires, such as multiple fires, the presence of incendiary devices or trailers, and the presence of ignitable liquids at the area of origin (see Section 23.2). While this is an important aspect of their responsibilities in the investigation of the fire cause, it is only a small part.

17.3.5.1.2 Prompt control and extinguishment of the fire protects evidence. The ability to preserve the fire scene is often an important element in the investigation. Even when fire officers and firefighters are not responsible for actually determining the origin or cause of the fire, they play an integral part in the investigation by preserving the fire scene and physical evidence.

17.3.5.2 Preservation. Once an artifact or other evidence has been discovered, preliminary steps should be taken to preserve and protect the item from loss, destruction, or movement. The person making the discovery should notify the incident commander as soon as practical. The incident commander should notify the fire investigator or other appropriate individual or agency with the authority and responsibility for the documentation and collection of the evidence.

17.3.5.3 Caution in Fire Suppression Operations. Fire crews should avoid causing unnecessary damage to evidence when using straight-stream hoselines, pulling ceilings, breaking windows, collapsing walls, and performing overhaul and salvage.

17.3.5.3.1 Use of Water Lines and Hose Streams. When possible, firefighters should use caution with straight-stream applications, particularly at the base of the fire, because the base of the fire may be the area of origin. Evidence of the ignition source can sometimes be found at the area of origin. The use of hoselines, particularly straight-stream applications, can move, damage, or destroy physical evidence that may be present.

(A) The use of water hoselines for overhaul operations such as washing down, or for opening up walls or ceilings, should also be restricted to areas away from possible areas of origin.

(B) The use of water should be controlled in areas where the investigator may wish to look at the floor for possible fire patterns. When draining the floor of standing water, the drain

hole should be located so as to have the least impact on the fire scene and fire patterns.

17.3.5.3.2 Overhaul.

(A) It is during overhaul that any remaining evidence not damaged by the fire is susceptible to being destroyed or displaced. Excessive overhaul of the fire scene prior to the documentation and analysis of fire patterns can affect the investigation, including failure to determine the area of origin.

(B) While the firefighters have a responsibility to control and extinguish the fire and then check for fire extension, they are also responsible for the preservation of evidence. These two responsibilities may appear to be in conflict and, as a result, it is usually the evidence that is affected during the search for hidden fire. However, if overhaul operations are performed in a systematic manner, both responsibilities can be met successfully.

17.3.5.3.3 Salvage. The movement or removal of artifacts from a fire scene can make the reconstruction difficult for the investigator. If the investigator cannot determine the prefire location of the evidence, the analytical or interpretative value of the evidence may be lost. Moving, and particularly removing, contents and furnishings or other evidences at the fire scene should be avoided until the documentation, reconstruction, and analysis are completed.

17.3.5.3.4 Movement of Knobs and Switches. Firefighters should refrain from turning knobs and operating switches on any equipment, appliances, or utility services at the fire scene. The position of components, such as the knobs and switches, may be a necessary element in the investigation, particularly in developing fire ignition scenarios or hypotheses. These components, which are often constructed of plastics, can become very brittle when subjected to heating. Their movement may alter the original post-fire state and may cause the switch to break or to become impossible to relocate in its original post-fire position. (See 25.5.3.)

17.3.5.3.5 Use of Power Tools. The use of gasoline- or diesel-powered tools and equipment should be controlled carefully because this type of equipment could be a source of contamination. The refueling of any fuel-powered equipment or tools should be done outside the perimeter of the fire scene. Whenever fuel-powered equipment is used on the fire scene, its use and location should be documented and the investigator advised.

17.3.5.3.6 Limiting Access of Fire Fighters and Other Emergency Personnel. Access to the fire scene should be limited to those persons who need to be there. This precaution includes limiting firefighters and other emergency or rescue personnel to those necessary for the task at hand. When possible, the activity or operation should be postponed until the evidence has been documented, protected, evaluated, and collected.

17.3.6 Role and Responsibilities of the Fire Investigator. If the firefighters have not taken the preliminary steps to preserve or protect the fire scene, then the fire investigator should assume the responsibility for doing so. Then, depending on the individual's authority and responsibility, the investigator should document, analyze, and collect the evidence.

17.3.7 Practical Considerations. The precautions in this section should not be interpreted as requiring the unsafe or infinite preservation of the fire scene. It may be necessary to

repair or demolish the scene for safety or for other practical reasons. Once the scene has been documented by interested parties and the relevant evidence removed, there is no reason to continue to preserve the scene. The decision as to when sufficient steps have been taken to allow the resumption of normal activities should be made by all interested parties known at that time.

17.4 Contamination of Physical Evidence. Contamination of physical evidence can occur from improper methods of collection, storage, or shipment. Like improper preservation of the fire scene, any contamination of physical evidence may reduce the evidentiary value of the physical evidence.

17.4.1 Contamination of Evidence Containers.

17.4.1.1 Unless care is taken, physical evidence may become contaminated through the use of contaminated evidence containers. For this reason, the fire investigator should take every reasonable precaution to ensure that new and uncontaminated evidence containers are stored separately from used containers or contaminated areas.

17.4.1.2 One practice that may help to limit a possible source of cross-contamination of evidence collection containers, including steel paint cans or glass jars, is to seal them immediately after receipt from the supplier. The containers should remain sealed during storage and transportation to the evidence collection site. An evidence collection container should be opened only to receive evidence at the collection point, at which time it should be resealed pending laboratory examination.

17.4.2* Contamination During Collection. Most contamination of physical evidence occurs during its collection. This is especially true during the collection of liquid and solid accelerant evidence. The liquid and solid accelerant may be absorbed by the fire investigator's gloves or may be transferred onto the collection tools and instruments.

17.4.2.1 Avoiding cross-contamination of any subsequent physical evidence, therefore, becomes critical to the fire investigator. To prevent such cross-contamination, the fire investigator can wear disposable plastic gloves or place his or her hands into plastic bags during the collection of the liquid or solid accelerant evidence. New gloves or bags should always be used during the collection of each subsequent item of liquid or solid accelerant evidence.

17.4.2.2 An alternative method to limit contamination during collection is to utilize the evidence container itself as the collection tool. For example, the lid of a metal can may be used to scoop the physical evidence into the can, thereby eliminating any cross-contamination from the fire investigator's hands, gloves, or tools.

17.4.2.3 Similarly, any collection tools or overhaul equipment such as brooms, shovels, or squeegees utilized by the fire investigator need to be cleaned thoroughly between the collection of each item of liquid or solid accelerant evidence to prevent similar cross-contamination. The fire investigator should be careful, however, not to use waterless or other types of cleaners that may contain volatile solvents.

17.4.3 Contamination by Fire Fighters. Contamination is possible when firefighters are using or refilling fuel-powered tools and equipment in an area where an investigator later tests for the presence or omission of an ignitable liquid. Firefighters

should take the necessary precautions to ensure that the possibility of contamination is kept to a minimum, and the investigator should be informed when the possibility of contamination exists.

17.5 Methods of Collection.

17.5.1 General. The collection of physical evidence is an integral part of a properly conducted fire investigation.

17.5.1.1 The method of collection of the physical evidence is determined by many factors, including the following:

- (1) *Physical State.* Whether the physical evidence is a solid, liquid, or gas
- (2) *Physical Characteristics.* The size, shape, and weight of the physical evidence
- (3) *Fragility.* How easily the physical evidence may be broken, damaged, or altered
- (4) *Volatility.* How easily the physical evidence may evaporate

17.5.1.2* Regardless of which method of collection is employed, the fire investigator should be guided by ASTM standards as well as by the policies and procedures of the laboratory that will examine or test the physical evidence.

17.5.2 Documenting the Collection of Physical Evidence.

17.5.2.1 Physical evidence should be thoroughly documented before it is moved. This documentation can be best accomplished through field notes, written reports, sketches, and diagrams, with accurate measurements and photography. The diagramming and photography should always be accomplished before the physical evidence is moved or disturbed. The investigator should strive to maintain a list of all evidence removed and of who removed it.

17.5.2.2 The purpose of such documentation is twofold. First, the documentation should assist the fire investigator in establishing the origin of the physical evidence, including not only its location at the time of discovery, but also its condition and relationship to the fire investigation. Second, the documentation should also assist the fire investigator in establishing that the physical evidence has not been contaminated or altered. (See 16.2.8.8.)

17.5.3 Collection of Traditional Forensic Physical Evidence. Traditional forensic physical evidence includes, but is not limited to, finger and palm prints, bodily fluids such as blood and saliva, hair and fibers, footwear impressions, tool marks, soils and sand, woods and sawdust, glass, paint, metals, handwriting, questioned documents, and general types of trace evidence. Although usually associated with other types of investigations, these types of physical evidence may also become part of a fire investigation. The recommended methods of collection of such traditional forensic physical evidence vary greatly. As such, the fire investigator should consult with the forensic laboratory that will examine or test the physical evidence.

17.5.4 Collection of Evidence for Accelerant Testing. An accelerant is any fuel or oxidizer, often an ignitable liquid, used to initiate a fire or increase the rate of growth or speed the spread of fire. Accelerant may be found in any state—gas, liquid, or solid. Evidence for accelerant testing should be collected and tested in accordance with ASTM E3245, *Standard Guide for Systematic Approach to the Extraction, Analysis, and Classification of Ignitable Liquids and Ignitable Liquid Residues in Fire Debris Samples*.

17.5.4.1 Liquid Accelerant Characteristics. Liquid accelerants have unique characteristics that are directly related to their collection as physical evidence. These characteristics include the following:

- (1) Liquid accelerants are readily absorbed by most structural components, interior furnishings, and other fire debris.
- (2) Generally, liquid accelerants float when in contact with water; however, alcohol is a noted exception.
- (3) Liquid accelerants have remarkable persistence (i.e., survivability) when trapped within porous material.

17.5.4.2 Canine-Handler Teams. Canine-handler teams have a role in fire investigations, including assisting in locating and collecting samples for laboratory analysis. See Section 17.7 for more information about canine-handler teams.

17.5.4.3 Collection of Liquid Samples for Ignitable Liquid Testing. When a possible ignitable liquid is found in a liquid state, it can be collected using any one of a variety of methods. However, the fire investigator should be certain that the evidence does not become contaminated by whichever method is employed. If readily accessible, the liquid may be collected with a new syringe, eye dropper, pipette, siphoning device, or the evidence container itself. Sterile cotton balls or gauze pads may also be used to absorb the liquid. This method of collection results in the liquid becoming absorbed by the cotton balls or gauze pads. The cotton balls or gauze pads and their absorbed contents then become the physical evidence that should be sealed in an airtight container and submitted to the laboratory for examination and testing.

17.5.4.4 Collection of Liquid Evidence Absorbed by Solid Materials. Often, liquid accelerant evidence may be found only where the liquid accelerant has been absorbed by solid materials, including soils and sands. This method of collection merely involves the collection of these solid materials with their absorbed contents. The collection of these solid materials may be accomplished by scooping them with the evidence container itself or by cutting, sawing, or scraping. Raw, unsealed, or sawed edges, ends, nail holes, cracks, knot holes, and other similar areas of wood, plaster, sheet rock, mortar, or even concrete are particularly good areas to sample. If deep penetration is suspected, the entire cross-section of material should be removed and preserved for laboratory evaluation. In some solid material, such as soil or sand, the liquid accelerant may absorb deeply into the material. The investigator should therefore remove samples from a greater depth. In those situations where liquid accelerants are believed to have become trapped in porous material, such as a concrete floor, the fire investigator may use absorbent materials such as lime, diatomaceous earth, or non-self-rising flour. This method of collection involves spreading the absorbent onto the concrete surface, allowing it to stand for 20 to 30 minutes, and securing it in a clean, airtight container. The absorbent is then extracted in the laboratory. The investigator should be careful to use clean tools and containers for the recovery step, because the absorbent is easily contaminated. A sample of the unused absorbent should be preserved separately for analysis as a comparison sample.

17.5.4.5 Collection of Solid Samples for Accelerant Testing. Solid accelerant may be common household materials and compounds or dangerous chemicals. Because some incendiary materials remain corrosive or reactive, care should be taken in packaging to ensure that the corrosive residues do not attack the packaging container. In addition, such materials should be handled carefully by personnel for their own safety.

17.5.4.6* Comparison Samples. When physical evidence is collected for examination and testing, it is often necessary to also collect comparison samples.

17.5.4.6.1 The collection of comparison samples is especially important in the collection of materials that are believed to contain liquid or solid accelerant. For example, the comparison sample for physical evidence consisting of a piece of carpeting believed to contain a liquid accelerant would be a piece of the same carpeting that does not contain any of the liquid accelerant. Comparison samples allow the laboratory to evaluate the possible contributions of volatile pyrolysis products to the analysis and also to estimate the flammability properties of the normal fuel present.

17.5.4.6.2 When collected for the purpose of identifying the presence of accelerant residue, the comparison sample should be collected from an area that the investigator believes is free of such accelerants, such as under furniture or in areas that have not been involved in the fire. Assuming that the comparison sample tests negative for ignitable liquids, any ignitable liquids that are found in the suspect sample can be shown to be foreign to the area when the suspect sample was taken.

17.5.4.6.3 It is recognized that comparison samples may be unavailable due to the condition of the fire scene. It is also recognized that comparison samples are frequently unnecessary for the valid identification of ignitable liquid residue. The determination of whether comparison samples are necessary is made by the laboratory analyst, but because it is usually impossible for an investigator to return to a scene to collect comparison samples, they should be collected at the time of the initial investigation.

17.5.4.6.4 If mechanical or electrical equipment is suspected in the fire ignition, exemplar equipment may be identified and collected or purchased as a comparison sample.

17.5.5 Collection of Gaseous Samples. During certain types of fire and explosion investigations, especially those involving fuel gases, it may become necessary for the fire investigator to collect a gaseous sample. The collection of gaseous samples may be accomplished by several methods.

17.5.5.1 The first method involves the use of commercially available mechanical sampling devices. These devices merely draw a sample of the gaseous atmosphere and contain it in a sample chamber or draw it through a trap of charcoal- or polymer-adsorbing material for later analysis.

17.5.5.2 Another method is the utilization of evacuated air-sampling cans. These cans are specifically designed for taking gaseous samples.

17.5.6 Collection of Electrical Equipment and System Components. Before attempting to collect electrical equipment or components from circuits of a power distribution system, the fire investigator should verify that all sources of electricity are off or disconnected. All safety procedures described in Chapter 13 should be followed. Electrical equipment and components may be collected as physical evidence to assist the fire investigator in determining whether the component was related to the cause of the fire.

17.5.6.1 Electrical components, after being involved in a fire, may become brittle and subject to damage if mishandled. Therefore, methods and procedures used in collection should preserve, as far as practical, the condition in which the physical